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THE FUTURE DEVELOPMENT OF ELECTRICAL APPLIANCES.

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From the "Journal of the Society of Arts."

It had been my intention to introduce this subject to your notice by speaking of the great things physical science has already done for humanity. I assure you, that I had arranged a most effective harangue on this subject, touching on the Bacons, and Newton, and Boyle, and Watt, and Faraday, and Joule, and Thomson, showing that it was these men in their laboratories who opened the way for Stephenson, Wheatstone and Cooke, Gramme, Hughes, Edison, and Graham Bell. I meant to tell you how, in days gone by, a few Birmingham business men subscribed to give their townsman, Priestley, sufficient money to live upon while working at original research; and I felt able to prove so clearly to you, that it was for the good of the nation to provide scientific men with large laboratories, and to ensure them freedom from ordinary cares, that in the mere preface to my proper subject, I prepared an hour's lecture. Luckily, I remembered that you had all had opportunities of hearing about the benefits you owe to science; and I bethought me that you might even be tired of listening to truisms regarding endowment of research; truisms to members of the Society of Arts, but not so well believed in by the general public, and especially by that section of the general public which sees reason to lean on Mr. Ruskin, in whose nostrils the mere names of Watt and Stephenson are as the savory odors of the Thames at low water, and attends to the views of Sir John Ellesmere, who hated telegrams more than he disliked our common enemy. Men of this stamp may well think of the future with horror, for there is every sign that applied science is increasing the acceleration of the rate of its development. To such men I would say: Put a stop to laboratory work; set your faces against the endowment of research; root up the acorn if you would not in the future be plagued with the oak. The applied science of the future lies invisible and small in the operations of the men who work at pure chemistry and physics. These men do not know what will be the outcome of their labors. They often think that they sympathize with Mr. Ruskin; but you might as well ask a dram drinker to give up that which his soul loveth, as ask a man who has done real experimental work to give it up. I have often watched Sir William Thomson, to whom every object in nature is continually suggesting new ideas, new experiments; to whom every particle of brass scraped off by a file is a being full of complication, an object of interest, and a thing of beauty, and to whom the study of the bending of a bit of brass wire is a joy for ever. Sir William

Thomson believes in applied science, but such belief has really nothing to do with the delight which he and every other experimenter has in his work.

Now, electrical science has reached a position from which, on every side, hundreds of enticing paths lead forward into unexplored regions of nature. At every step in advance, the laboratory worker sees to right and left of him new and promising lines of research; and he feels that, for the work to be done, the present army of explorers is all too small and weak. But interesting as it might be to prophesy on investigations newly begun, it is rather my purpose, to-night, to take you upon the well-trodden ground prepared for us by Faraday, and Joule, and Thomson, to show you how, in one or two great lines of the applied science of electricity, certain fixed laws tell us about the future. I shall then speak of a few of the more recent discoveries.

Now, in the first place, you must remember that electricity is, to us, something that can be measured; although, unfortunately, to the ordinary telegraph operator, this is not the case. If you can imagine a mechanical engineer regarding a distance of a few inches as being equal to the distance of a few miles, or even of a few thousand miles; if you can imagine a grocer to confound an ounce of sugar with a ship's load of the same material, you get a too truthful idea of the vagueness, the general want of definiteness, in the notions of nearly all students of this subject until a few years ago, and, I am sorry to say, that much of this vagueness is still to be found even in modern scientific papers. Perhaps, when electricity is supplied to every house in the City of London at a certain price per horse power, and is used by private individuals for many different purposes, this vagueness will finally disappear.

To get exact ideas in any department of physics, we have one firm foundation to build upon, viz., that a certain amount of energy or power of doing work remains always the same, in whatever form it may appear. I have here various sources of electricity—a voltaic cell, a thermopile, a glass-plate machine, a magneto-electric machine, which may be turned by hand, and two dynamo-electric machines outside, which I can drive by means of a steam engine. As you know, there are many others. To all these, some form of energy is given, and they convert this energy, badly or well, into electric energy. The cell burns zinc; in the thermopile gas is burnt; to the three last machines mechanical energy is given; they all give out electrical energy. Now, how do we know that there is a production of electrical energy? Let us take any one of them—this voltaic cell, for instance. Some form of energy is given out, for you see that I can convert it into heat. (Experiment shown.) Here I take advantage of a property somewhat analogous to mechanical friction.

This thermopile is also generating electricity. To test this I connect its poles to the wire of a galvanometer, and the instantaneous deflection of the needle of the galvanometer tells me about the current. (Experiment shown.) Here is another proof that some kind of energy is traversing the wire connecting these two screws. The two wires are attached to an arrangement at the other end of the room; when I complete the circuits, whether I do it here or there, the bell rings. (Experiment shown.) You see that in this case the heat energy given out by this burning gas is converted partly into electrical energy, in which state it can be transmitted to a considerable distance, and there converted into mechanical energy, or into sound, or into any other form of energy. In these and other ways we can detect the existence of the electrical energy coming from all these generators, and measure its amount. Now, Joule's experiments tell us that any generator gives out exactly as much energy as is given to it, but much appears in the form of heat. All these generators get heated, and may be said, therefore, to waste energy. One great object of the inventors of such machines is, to give out as much as possible of the energy supplied to them in the shape of electrical energy. You must clearly distinguish between electricity and electrical energy. A miller does not merely speak of the quantity of water in his mill-dam; he has also to consider the height through which it can fall. A weight of one thousand pounds falling through a distance of one inch represents the same energy, that is, gives out the same amount of work in falling as one pound

through one thousand inches. A mere statement, then, of the quantity of electricity given out by a machine is insufficient; it is also necessary to state what is the height or difference of potential through which it is falling. The quantity of electricity in a thunder cloud is comparatively small, but the difference of potential through which this quantity passes when discharge occurs is exceedingly great. So it is with the two factors of the electrical energy developed by this glass machine. The quantity of electricity obtainable from this machine is comparatively small, but it is like a small quantity of water at an exceedingly great height, whereas, in all these other machines we have, in the analogy of the miller, a very great quantity of water and a very small difference of level. I put this water analogy before you because you have all more or less exact notions about water, and because, within certain limits, the analogy is a very true one. I have traced it more fully in the wall-sheet I.

WALL-SHEET I.

We Want to Use Water.	*We Want to Use Electricity.*
1. Steam pump burns coal and lifts water to a higher level.	1. Generator burns zinc, or uses mechanical power, and lifts electricity to a higher level or potential.
2. Energy available is, amount of water lifted × difference of level.	2. Energy available is, amount of electricity × difference of potential.
3. If we let all the water flow away through channel to lower level without doing work, its energy is all converted into heat because of frictional resistance of pipe or channel.	3. If we let all the electricity flow through a wire from one screw of our generator to the other without doing work, all the electrical energy is converted into heat because of resistance of wire.
4. If we let water work a hoist as well as flow through channels, less water flows than before, less power is wasted in friction.	4. If we let our electricity work a machine as well as flow through wires, less flows than before, less power is wasted through the resistance of the wire.
5. However long and narrow may be the channels, water may be brought from any distance, however great, to give out almost all its original energy to a hoist. This requires a great head and small quantity of water.	5. However long and thin the wires may be, electricity may be brought from any distance, however great, to give out almost all its original energy to a machine. This requires a great difference of potentials and a small current.

You will readily understand, then, that for some purposes it is necessary to have our electrical energy in the shape of a small quantity of electricity falling through a great difference of potential, and for other purposes a great quantity of electricity falling through a small difference of potential. When electricity falls through a difference of potential, this difference is called an electro-motive force. It would take me too long to tell you why we use two terms to express what seems to be the same thing; but briefly, the term "difference of potential" is analogous with "difference of pressure" or "head" of water, howsoever produced; whereas electro-motive force is analogous with the difference of pressure before and behind a slowly moving piston of the pump employed by an unfortunate miller to produce his water supply.

The first object of my paper is to show you that electricians have very definite ideas on the subjects they are working at; that the measurements, on which their work depends, have exact meanings, and that there is hardly any problem in adding to man's powers which you can set before them to solve which they may not hope to do with more or less costly apparatus. Everybody knows that the civil engineer is still very far from having reached the limiting lengths or sizes to which large bridges and other structures may be built, at a greater or less cost. Everybody is competent to form a roughly correct judgment in such matters, because everybody has more or less correct notions about sizes, weight, and strength of materials. And in the same way that you may be able to guess of what the electrician may do in the future, it is necessary that you get fairly correct ideas of electrical magnitudes; and the curious fact is that, seeing how simple it is to arrive at these correct ideas, so few people possess them. On the wall-sheets II and III, I have given such help as can be given visibly in this matter; but time will not allow of my entering into such explanatory details as I should desire.

WALL-SHEET II.—ELECTRICAL MAGNITUDES. (SOME RATHER APPROXIMATE.)

Resistance of	
One yard of copper wire, one-eighth of an inch diameter.....	0.002 ohm

One mile ordinary iron telegraph wire.....	10 to 20 ohms
Some of our selenium cells.	40 to 1,000,000
A good telegraph insulator.	4,000,000,000,000

Electromotive force of	Volts.
A pair of copper-iron junctions at a difference of temperature of 1° Fahr..... =	0.000,01
Contact of zinc and copper... =	0.75
One Daniell's cell..... =	1.1
Mr. Latimer Clark's standard cell..... ..... =	1.45
One of Dr. De la Rue's batteries..... =	11,000

Lightning flashes probably many millions of volts.

Current measured by us in some experiments:

Using electrometer..... =	almost infinitely small currents.
	Weber.
Using delicate galvanometer..... ..... . =	0.000,000,000,040
Current received from Atlantic cable, when 25 words per minute are being sent..... =	0,000,001
Current in ordinary land telegraph lines... ..... =	0.003
Current from dynamo machine.... ..... =	5 to 100 Webers
In any circuit, *current* in webers..... =	*electromotive force* in volts ÷ *resistance* in ohms.

WALL-SHEET III.—RATE OF PRODUCTION OF HEAT, CALCULATED IN THE SHAPE OF HORSE POWER.

In the whole of a circuit = *current* in webers × *electromotive force* in volts ÷ 746.

In any part of circuit = *current* in webers × *difference of potential* at the two ends of the part of the circuit in question ÷ 746.

Or, = square of current in webers × resistance of the part in ohms ÷ 746.

If there are a number of generators of electricity in a circuit, whose electromotive forces in volts are $-E_1$, E_2, &c., and if there are also opposing electro-motive forces, F_1, F_2, &c., volts, and if C is the current in webers, R the whole resistance of the circuit in ohms, P the total horse power taken in at the generators, Q the total horse power converted into some other form of energy and given out at the places where there are opposing electromotive forces, H the total horse power wasted in heat, because of resistance, then:

$$C = \frac{(E_1 + E_2 + \&c.) - (F_1 + F_2 + \&c.)}{R}$$

$$P = \frac{C}{746}(E_1 + E_2 + \&c.); \quad Q = \frac{C}{746}(F_1 + F_2 + \&c.);$$

$$H = \frac{^2CR}{746}.$$

The lifting power of an electro magnet of given volume is proportional to the heat generated against resistance in the wire of the magnet.

The future of many electrical appliances depends on how general is the public comprehension of the lessons taught by these wall sheets. If a few capitalists in London would only spend a day or two in learning thoroughly what they mean, I am quite sure that electrical appliances of a very distant future would date from a few months hence.

It is not necessary for me to tell you now that electrical energy may be produced. Nor need I waste time in speaking of how it may be transmitted to a distance by means of insulated metal wires. A more important fact is that, when electricity is flowing in a wire, I can transform part of its energy into other shapes. For instance, here is an iron wire of 2 ohms resistance. Suppose this to be in a cold room, and I turn on the electricity tap. (An electric machine, driven outside by a gas engine, is here my source of energy.) This wire is now getting a supply of electrical energy, and is converting it into heat. Mr. Andrews tells me that there is now a current of 20 webers flowing through the wire, and hence the wire is giving out more than one horse power in the shape of heat. Some of you may have thought that very little heat can be given out by such a wire; but these are the exact figures, and you can all see that they represent a pretty large supply. When the current has been flowing for a short time, the neighborhood of this wire will be found unpleasantly warm, and I can assure you that the use of this instrument for certain measuring purposes is very disagreeable in the summer time. It is hardly necessary to say that a wire, through which a current is flowing, may be made to give out its heat for a great variety of purposes. The temperature may be pretty much what we please. Thus, I turn the tap, and this wire gives off very intense heat. (Experiment shown.)

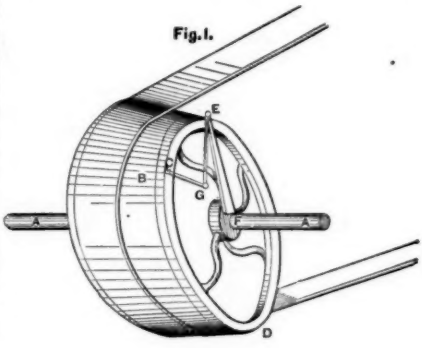
I had asked my friend, Mr. Andrews, to boil water for you by means of a hot spiral wire; but he has given us something of his own which is very much better. You see that I turn this tap, and so pass this current among all these little bits of carbon; first we have bright spots of light here and there stealing from point to point; then these lights fix themselves in definite places, and

round them the carbon gets red hot, until we get in two minutes the most perfect form of fire for heating a room or boiling a kettle that I have ever seen. I have in vain tried to get Mr. Andrews to exhibit before you to-night his exquisitely simple plate electric light. I have watched it burning, and knew that it has a future before it, if it were only from the fact that it burns steadily for a whole week with a powerful arc light without renewal of the carbons, and yet these carbons might be put in one's pocket, and the lamp thrown about anyhow, without risk of anything getting out of order. The excessive caution of the inventor prevents my showing you this simple little lamp. My own lamp is here before you, but beyond telling you that it is very simple, and that only one magnet is employed in the regulation and separation work, I may not detain you. I now turn another tap, and the strip, through which the current passes, becomes white hot, and we call it, vaguely, an electric light. (Experiment shown.) This is the incandescent light which has been proposed for use in ordinary houses. It is, confessedly, not econominal, but it is very convenient for chamber use. I now turn another tap, and you see a powerful Serrin lamp, which I mean to leave burning. You know now that we can convert electrical energy into heat and light; but the question is, how much of a result do we get for the power expended?

Professor Ayrton and his students measure at Cowper street, 1st, how much gas is being used by his gas engine; 2d, how much horse power is being actually given to his electric machine; 3d, how much current is produced through external circuits by his machine; 4th, the resistance of these circuits. He can now calculate exactly how much horse power is expended in any part of these circuits, and also how much light is actually given out by an electric lamp.

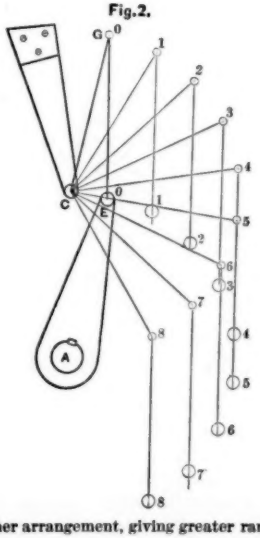
I must now try to give you an idea as to how these measurements are made. The very elegant dynamometer employed by our Chairman to measure the power which is being transmitted to a machine, I am not at liberty to describe. The plan devised by Professor Ayrton and myself is capable of being applied at very small cost to existing shafting in factories, so that the power given to any shaft may be known. A is a shaft which is to receive power. B is a loose pulley driven by a belt. C D is a wheel whose

Fig. 1.



rim is fixed to the rim of B; its crooked arms are made of flexible steel, its boss being keyed to the shaft. Evidently B can no longer be called a loose pulley, if it turns it must cause the shaft to turn, but the turning moment is accurately represented by a certain amount of yielding of the steel arms of C D. If this yielding is known, and also the speed, the horse power transmitted is also known. For, so far, we copy the principle of General Morin. But instead of

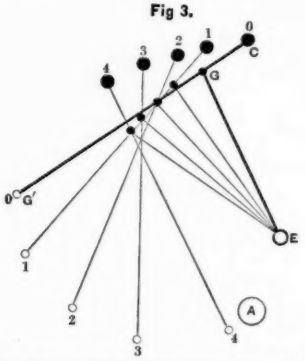
Fig. 2.



Another arrangement, giving greater range.

using his elaborate system of measurement, we simply convert the tangential strain into a radial motion which is visible. This may be done in various ways, of which the following is the most simple. A stiff arm, EA, is fixed to the shaft at A; at E and at a point C of the wheel, the ends of two light links are pivoted, which are hinged together at G, where there is a bright bead. Evidently,

Fig 3.



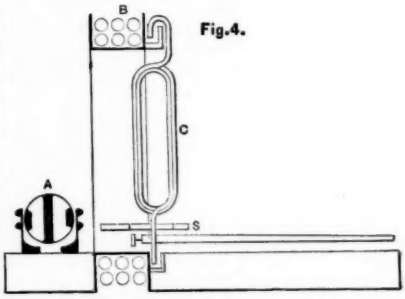
When tangential strain is small, this method of range is used.

if the distance CE becomes large, because much power is being transmitted, the bead G moves out from the center, and therefore the circle of light described by it has a greater radius. The arrangement shown in Fig. 3 is sometimes more convenient.

We measure the distance of the bead from the axis by means of a scale supported level with the shaft. Other dynamometers, which have till now been in use are shown in the diagrams. For measuring very strong currents, such as are used in electric lighting, Professor Ayrton and myself have devised this "dead-beat" galvanometer. Without going into a detailed description of the instrument, I may mention that it possesses the following great advantages. Not only can the strength of any current be read off at once in webers, but the user can at any moment test his own instrument, or graduate it, as it is technically called, by employing only the weak current produced by a single Daniell's cell. This result is arrived at by the device of causing the weak current to circulate 60 times round the magnets, while the strong current only goes round six times; a special form of commutating arrangement enabling the very same wires in the galvanometer to serve for both strong and weak currents; hence, comparisons can be made, not merely approximately, but with absolute accuracy, even if the wires are wound on the galvanometer quite carelessly.

The instrument shown in this diagram may be graduated in the same manner, as it is also provided with the same kind of commutator. We call it an arc-horse-power measurer, because its deflections

Fig.4.



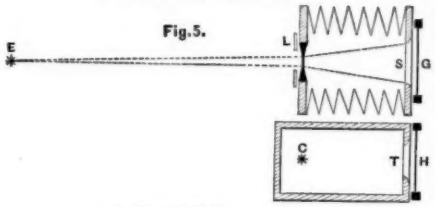
B, fixed coiled cable of ten strands, which may be used in "parallel arc" or in "series," by means of the commutator, A.
C, moveable coil.
S, spiral spring.

are proportional to the product of difference of potential established in an electric light, into current flowing through the arc, or incandescent carbon, and hence these deflections (see wall sheet II., p. 91) show at a glance the horse power given out at that place. The electro-dynamometers of Dr. Siemens and of Mr. Andrews are here before you, and may be used during the reading of the paper to measure currents. Mr. Andrews simply uses a steelyard to balance the attraction between two coils, when the current flows in them, when they are at a fixed distance asunder, and he, therefore, like Dr. Siemens, measures the mean square of the current flowing. These instruments have the disadvantage that an ordinary pair of scales has in comparison with a spring balance, viz., that a sudden temporary change in the thing weighed cannot be measured; but they have the advantage of great accuracy in the measurement of a constant effect.

To measure the light itself in standard candles, the students in the course of electric lighting, at Cowper street, employ our photometer (Fig. 5), of which three specimens are before you, and there is an enlarged drawing on the

DISPERSION PHOTOMETER.

Fig.5.



E, electric light.
C, standard candle.
S and T, screens of tissue paper.
G, H, plates of green or red glass.

$$E \propto \frac{E L^2 . L S^2}{C T^2}$$

wall. The principle of old methods of measurement of strong lights was to weaken the intensity of illumination of a screen by taking the screen far enough away. Only in this way could the illumination of the screen by the electric light be made equal to the illumination of a similar screen by a standard candle. Our plan of weakening the light from an electric lamp is not by going forty or eighty feet away from it—for people who deal with electric lamps do not often possess a large enough chamber with blackened walls—but by letting, instead, the light pass through a concave lens. The principle is then exceedingly simple. Mr. Wormell has been making a few measurements whilst I have been talking, and I see that this electric light seen through green glass has varied from 2.214 to 2.136 candles in the last three minutes. Sir William Thomson suggested to us to make two measurements, one through green and the other through red glass, for reasons which must be obvious. Any one who may wish it will have an opportunity of measuring the power of an electric light for himself after the lecture.

From all this you will see that perfect methods exist for measuring the power which is being given out as heat or light in any part of a circuit, as well as the power given to the electrical machine. In fact, we have a perfect measure of what is called the efficiency of our arrangement.

It is hardly necessary to tell you that every house and every street may be lighted electrically. Into the proof that, in the future, arc lamps of thousands of candle power at elevations proportional to the square roots of their powers, will be used for large spaces, and that incandescent lamps of only hundreds of candle power are suitable only for private houses; into a consideration of these statements I shall not enter, because Professor Adams is dealing with the question in his Cantor lectures. You all, in one way or another, feel that electric lighting is a foregone conclusion. But, perhaps, you were not aware that buildings may be heated by electricity. The neighbors of this iron wire will say that it gives out a considerable quantity of heat, but whether the heating may be performed economically will depend on the story told us by the measurements which have been made. Now let me turn my tap again. I let my current pass through this insignificant little dynamo machine, and you observe that it is in motion; not only is it in motion itself, but it is driving this lathe. A machine is receiving mechanical energy outside, it converts this into electrical energy, which is conveyed by wires into the room and to the machine before you, where it is converted into mechanical energy again. I think I shall never forget the astonishment of a workman in Sheffield, who had put up a saw bench for use at Professor Ayrton's lecture, and who was about to rehearse his part. He looked at the motionless saw, he had his hand on the wood, he saw there was a belt from a little mite of an electric machine, two wires dangled from the ceiling to the machine, and that was all. What notions of being played with came into his mind I do not know, but when, at the distant place, a water engine was started to drive the distant machine, when the saw set off nearly at its full speed, and the two dangling wires were evidently the only methods of communication, this thoughtful workman's face expressed in full perfection the absence of all his reasoning powers. I do not wish you to lose your reasoning powers, but it is necessary that you should get thoroughly impressed with the notion that the

power to drive this lathe is actually being transmitted through these limp and motionless wires.

I should like to be able to hold that machine motionless, and to prove to you that the current flowing through the wires is immediately diminished when the machine begins to move. In fact, I want to show you that this machine produces an electromotive force, which is in opposition to that of the distant machine. You see that we are just able to hold it, and now I am informed that the current flowing is 19.5 webers, whereas if we let it run, and drive the lathe and the sewing machine and this fan, you will find that the current is diminished. It is 11.2 webers, or about half what it was before. It is not necessary to give you further examples of this transmission of power by electricity, but on account of the evident importance of the matter to the health of the community, I will give you one more, and I turn the tap, and you all see that the insignificant little machine is driving a ventilator. This ventilator might be used in a chimney in the summer time when fires are not in use, or in any suitable outlet from rooms; and pray remember that mechanical ventilation is ever so much more efficient than what is called natural ventilation, in which advantage is taken of the lightness of warm gases.

Now, what do these examples show you? They show that if I have a steam engine in my back yard, I can transmit power to various machines in my house, and if you measured the power given to these machines, you would find it to be less than half of what the engine driving the outside electrical machine gives to it. Further, when we wanted to think of the heating of buildings and the boiling of water, it was all very well to speak of the conversion of electrical energy into heat, but now we find that not only do the two electrical machines get heated and give out heat, but heat is given out by our connecting wires. We have then to consider our most important question. Electrical energy can be transmitted to a distance, and even to many thousands of miles, but can it be transformed at the distant place into mechanical or any other required form of energy, nearly equal in amount to what was supplied? Unfortunately, I must say that hitherto the practical answer made to us by existing machines is, "No;" there is always a great waste due to the heat spoken of above. But, fortunately, we have faith in the measurements of which I have already spoken, in the facts given us by Joule's experiments, and formulated in ways we can understand. And these facts tell us that in electric machines of the future, and in their connecting wires, there will be little heating, and therefore little loss. We shall, I believe, at no distant date, have great central stations, possibly situated at the bottom of coal pits, where enormous steam engines will drive enormous electric machines. We shall have wires laid along every street, tapped into every house, as gas pipes are at present; we shall have the quantity of electricity used in each house registered, as gas is at present, and it will be passed through little electric machines to drive machinery, to produce ventilation, to replace stoves and fires, to work apple parers, and mangles, and barbers' brushes, among other things, as well as to give everybody an electric light.

Probably you think it very strange that I should show you the ineffiency of electric transmission of energy, and then make this very bold assertion. Well, the fact is, that the ordinary electrical machines in use have not been constructed with a view to economy. They have been constructed to show that brilliant lights and considerable power may be produced from small machines. They have, at a comparatively small cost, attracted attention to the fact that electricity is an important agency. In so far they have done well; but on the other hand, they gave rise to the well-known assumption that 50 per cent. of the mechanical power given to the generator, was the maximum amount which could be taken from the motor. The true solution of the problem of transmission of power was, I believe, first given by Professor Ayrton in his British Association lecture at Sheffield. It had been supposed that to transmit the power of Niagara Falls to New York, a copper cable of enormous thickness would be needed. Mr. Ayrton showed that the whole power might be transmitted by a fine copper wire, if it could only be sufficiently well insulated. He

also showed that, instead of a limiting efficiency of 50 per cent., the one thing preventing our receiving the whole of our power was the mechanical friction which occurs in the machines. He showed, in fact, how to get rid of electrical friction. I will briefly give you our reasons. A machine at Niagara receives mechanical power, and generates electricity. Call this the generator, and remember that wall sheet III teaches us that the mechanical power is proportional to the electromotive force produced in the generator, multiplied into the current which is actually allowed to flow. Let there be wires to another electric machine in New York, which will receive electricity, and give out mechanical work, as this machine does here. Now, I showed you a little while ago, that this machine, which may be called the motor, produces a back electromotive force, and the mechanical power given out is proportional to the back electromotive force, multiplied into the current. The current, which is, of course, the same at Niagara as at New York, is proportional to the difference of the two electromotive forces, and the heat wasted is proportional to the square of the current. You see, then, from wall sheet III, that we have the simple proportion—power utilized is to power wasted, as the back electromotive force of the motor is to the difference between electromotive forces of generator and motor. This reason is very shortly and yet very exactly given in wall sheet IV.

Let electromotive force of generator be E; of motor F. Let total resistance of circuit be R. Then if we call P the horse power received by the generator at Niagara. Q the horse power given out by motor at New York, that is, utilized. H, the horse power wasted as heat in machines and circuit. C, the current flowing through the circuit.

$$C=\frac{E-F}{R}$$

$$P=\frac{E(E-F)}{746R}$$

$$Q=\frac{F(E-F)}{746R}$$

$$H=\frac{(E-F)^2}{746R}$$

$$Q : H :: F : E-F$$

To put it more shortly still, the power wasted is proportional to the square of the current flowing, whereas the power utilized is proportional to the current, and also to the electromotive force of the motor. The greater, then, we make the electro-motive forces, the less is the loss of power in the whole operation. Perhaps you will see this better from the water analogy. A small quantity of water flowing through a water main, may convey a large amount of energy, if it only has sufficient head. The frictional loss of power is independent of the head, but depends very much on the quantity of water. In the model before you is the water analogy. (Experiment shown.) A is a reservoir, kept filled with water by a steam pump, which draws the water from the sea level, K K. Water flows from reservoir A to distant reservoir, B, where it drives a turbine giving out work due to its head, B K. The current from A to B, through the communcating pipe, is the same always, so long as A and B are at the same difference of level, and therefore the frictional loss of energy is always the same, whereas the work utilized from B, by driving the turbine, increases proportionally to the height of B above sea level.

The result, then, to which the above laws led Professor Ayrton and myself was that for the future development of the transmission and distribution of electric energy it will be necessary to use electric machines of great electromotive force. Indeed, so important must this principle become, that we believe there is a future in this direction for the employment of plate electrical machines, such as that of Holtz. Now the electromotive force of an electric machine may be increased in three ways: 1. By increased speed, as you easily see when I turn this magneto machine more rapidly. 2. By increased strength of magnetic fields. 3. By increasing the length of wire on the moving armature. Of these methods the first is most important. Now, if iron is used in the armature, since it is magnetized and demagnetized very rapidly its coercitive force prevents this magnetization and demagnetization being as complete at the high speeds I contemplated, as it is at the ordinary speeds of the present

day. I say this in spite of the fact shown by some unpublished experiments of ours, which imply that the magnetization and demagnetization of a bundle of fine soft iron wires are as complete when effected sixty times per second as when effected once per second. Besides this, a very considerable quantity of heat is developed in such rapid magnetization and demagnetization as does occur. The electric machines of the future will, I am convinced, be without iron in their movable parts. High speeds necessitate careful construction and the balancing of moving parts, and great attention being given to rubbing surfaces. By rubbing surfaces, I do not merely mean the bearings of the machine, but the commutator, which is rubbed by the collecting brushes. Much of the waste of energy by mere mechanical friction which occurs in electric machines occurs at the brushes; but, hitherto, other waste has been so great that this might be neglected as unimportant. But it is very important in the machines of the future. The loss of energy by friction is proportional to the number of revolutions per minute, and to the diameter of the rubbing surface. I have given considerable thought to the reduction of this friction, and have arrived at a form of commutator shown at A in the diagram (Fig. 4), which largely dininishes the loss. The parts of the commutator must be firmly fixed, but they must also be well insulated from one another, therefore they must be separated by some rigid insulator, such as ebonite, at the places where they are screwed up; hence, they are necessarily far apart at these places. If they are rubbed at these places, however, there will be a great loss of power in friction, and hence they ought to be bent in towards the axis of rotation, where they may be insulated from one another by narrow air spaces, and where they may be rubbed by the brushes, with only a small waste of energy. This plan I have proved to be quite feasible. In the larger machines of the future, its importance will become much more manifest that it can be in existing machines. This frictional principle is illustrated by the model before you. Here are two surfaces, making the same number of revolutions per minute. If the same amount of rubbing occurs, you observe that when I rub the surface of larger diameter, there is great loss of energy, and the motion is stopped; whereas, when I rub the surface of smaller diameter, there is only a small loss of energy, and the motion is not stopped. (Experiment shown.)

This necessity for a great velocity of moving coils past fixed magnets, necessitates increase of size of the armature, because for a given velocity the centrifugal force tending to burst the revolving armature is inversely proportional to the radius. For instance, here are two light wheels, made in exactly the same way. You can examine their construction at the end of the meeting. They are rotated at a different number of revolutions per minute, so that the actual velocities of their rims shall be the same. You observe that the rim of the smaller bursts in pieces, and the larger is unhurt.

There is another important reason for increased size, namely, that of similar dynamo machines, one twice as large as the other: the larger is capable of giving out eight or more times as much energy for the same number of revolutions per minute. It would delay me too much to go into this question of size fully; but if it be remembered that the electromotive force of each moving coil is proportional to its area, then, without taking into account increase of strength of magnetic field, which certainly occurs with larger machines, we get eight times as much effect for double the size. Electric machines of the future will, then, probably, be of great size, moving with exceedingly great velocity.

The third method of increasing the electromotive force by having greater lengths of wire in the armature is always available, but inasmuch as every increase so produced causes a proportional increase in the resistance of the circuit, and therefore a waste by heating, this method is not quite so economical as the increase-of-speed method.

It is to be remembered that the lifting power produced in an electro-magnet of given size is simply proportional to the heat produced in the wire on the magnet, and if it is our object to diminish this heat, we must discard all idea of working the magnets of electric machines by their own currents. In fact,

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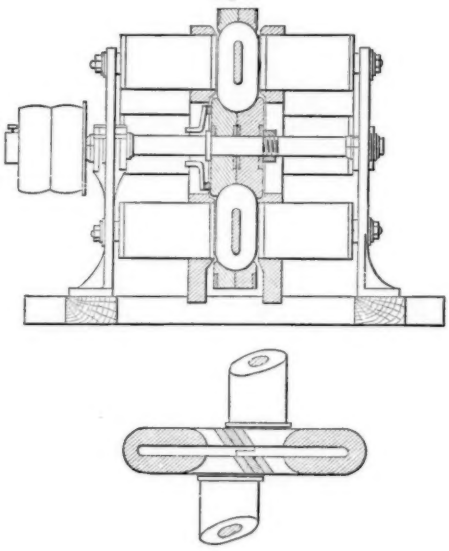
the function of dynamo machines, like these I have been using, will, in the future, be to feed the magnets of larger machines, or else they will give place altogether to magneto-electric machines. I have now given you, very briefly, some of the reasons which have occurred to us for believing that very large continuous current machines, with separate exciters, or, perhaps, even magneto-electric machines driven very fast by steam engines, will have an important place in the future transmission of energy by electrical methods. With such machines it would be possible to heat, light, and ventilate all the houses in New York, and to give to large and small workshops the power required to drive their machinery by means of an ordinary telegraph wire (but with some exceptionally good method of insulation), transmitting energy from as great a distance as the Falls of Niagara.

When I speak of what will be done in the future, in this direction, I can speak with perfect certainty. It is useless to tell us that existing machines are not economical. As I have already said, existing machines have been made with a very different purpose; to show that much electrical energy and striking light effects may be produced by a small and portable machine. They have drawn the attention of capitalists to electric lighting and electric railways, and in this way have done great service. Calculations of possible economy in the future, deduced from their action merely, must, however, be quite misleading. But if the facts given in this wall sheet are correct—and, fortunately, there can be no doubt of their correctness—the practical transmission of all kinds of power to all distances; the supply of large and small quantities of light and machine power to all parts of a city like London from a single center, and a consequent return to that old state in which in many trades it was possible to dispense with the congregation of great numbers of men in large manufactories, is a thing to be looked forward to with perfect certainty. I need hardly tell you that heating houses by electricity will completely get rid of the smoke nuisance. I have been dealing with general principles, and electricians will take various plans to carry out the idea put before you. In my own machine, exhibited here, and also drawn upon this diagram (Fig. 6), I

PERRY'S DYNAMO MACHINE.

Fig. 6.



have endeavored to carry them out in my own way. This is the largest machine which I could induce my kind friends, the firm of Messrs. Clark and Muirhead, to construct for me. I would, were money enough available, apply the principle to coils wound obliquely on the thin rim of a great fly-wheel of a large steam engine, fixing magnets obliquely to one another on both sides of the rim.

I have so much pecuniary interest in the future of this machine that it would take from the impersonal character of the lecture if I brought it before you too prominently. Its performance may be examined into at the manufactory. If time allowed, I would rather dwell on the enormous social phenomena which are preparing to develop themselves. England is a very rich country. She can afford, even through her Government which dispenses only a small portion of her wealth, to carry out great enterprises at the ends of the earth. By her canals and roads, and then by her railways, she has made herself comfortable, and has added to her wealth. Adding to her wealth is an accidental effect, perhaps, but adding to the happiness and health of the poorest people in this cradle of the Anglo-Saxon race is certainly the most important work to be effected by the wealth of England. To do this, through the agency of electricity, will not prove a bad financial investment.

Leaving this very large subject, let me speak of a few of the applications of the above principles which have a future before them. The development of the telephone and of telephone exchanges, until every person in London can speak directly with every other Londoner, and, indeed, with every other person in the country; this, as you all know, is quite a settled matter, although, no doubt, there are little difficulties still to be surmounted. At one end of a telephone wire there is a generator, a magneto-electro machine, which receives sound energy, and gives out electricity. At the other end there is a receiver, or motor, another such machine, which receives electric energy and gives out sound. We have, in fact, a simple example, and one of the most economical examples I know of, for the transmission of power by means of electricity. Quick speeds caused by vibrations of many hundred times per second, and strong magnetic fields, have produced this wonderful economy, which enables men in Paris to speak with members of their family in Marseilles. Again, the subject of electric railways is a part of the much larger subject which I have already dealt with. I suppose you all know the general principle of electric railways as hitherto constructed. Only that we like to observe large effects produced, the model which is now working before you would give as clear ideas of future constructions of this kind as the Berlin railway, or the one to be exhibited at Paris. [In this experiment a circular railway was worked from a magneto-electric machine driven by hand.] A generator of electricity is driven by a large stationary engine, somewhere in the neighborhood of the railway. A motor on a carriage receives electric energy by the conducting rails, and converts this into mechanical work to drive the carriage. Even the small experiments of Dr. Siemens show that there can be no doubt that the introduction of electric railways everywhere is merely a question of capital, and the sacrifice of much existing plant. This kind of proof was very much needed by capitalists. But the electrician sees much further; he sees better insulation for the conductor, and application of the above principles to hundreds of miles of rail instead of a thousand yards; he sees, in fact, that the larger the experiment, the greater must be its success. He looks forward to the absence of a vitiated atmosphere in our underground railways. He sees that the weight of rails (for there will be no heavy locomotive in the future; each carriage will have its own driving and braking machinery), and the cost of bridges, and wear and tear of permanent way, may become less than one-quarter of what they are at present; he sees, in fact, all the advantages that will arise, when, instead of making a heavy steam-engine travel backwards and forwards with carriages, the carriages alone travel, and the steam-engine is not near the railway at all. In that case, also, all the energy at present wasted in stopping a train, will simply be given back to the generator.

I have mentioned electric lighting, and telephones, and railways, because I know

that many of you must have expected to hear of them, but I mainly wish you to consider these appliances as examples simply of the transmission of power by electrical means. In the same way I might refer to a countless number of other appliances, giving you a mere catalogue of them; but, from the ordinary house-bell to the complicated arrangement by which my brother regulates the weirs on a river to prevent floods; from the time-regulating luxury of certain clockmakers, to the quadruplex telegraphy of Muirhead and Winter, they are simply methods of transmitting energy by electricity, and as such, their economical devolopment depends on the recognition of the above principles. Take, for example, the case of ordinary telegraphy. There can be no doubt that it is absurd to fill large houses with tens of thousands of voltaic cells to work telegraph lines. But it is not sufficient for the Post-office authorities to feel the annoyance, and merely try to replace batteries with such a machine as you see before you—a machine of but one *ohm* resistance, while every mile of telegraph wire may have twenty ohms resistance. I am sure that everybody belonging to the telegraph department will be satisfied with a change that gives them one dynamo machine for all those thousands of sloppy voltaic cells; and there is no longer any excuse for further delay, since Mr. Schwendler has been perfectly successful in working long telegraph lines in India in this very manner.

When we think of electricity as an agent by means of which energy may be transferred and altered, it is natural to ask if, by means of it, energy can be stored up. If we could obtain an efficient method of storing energy, the result would be of very great importance in a variety of ways. Thus, if all the work obtainable from the tide filling and emptying great shallow basins, could be stored up, so that it might be given out steadily, and only at our pleasure; if all the work obtainable from wind-power, which is constantly varying, could likewise be stored up, so as to be readily available, a long-standing difficulty would be got rid of, which has hitherto prevented the working out of large schemes for the utilization of these sources of natural power. And not only in these large cases, but in a countless number of other ways, is it important to possess means of storing energy. In the manufacture of gunpowder, and in many chemical operations, energy is stored up; but no such method can ever become economical. It has to be remembered, however, that electrical operations may be made as economical as we please; and however insignificant the method may appear to be just now, it may assume great importance in the future, from the fact that, with the exception of the lifting of heavy bodies to higher levels, an electrical method of storage may be made more economical than any other. Now when I charge this Leyden jar (experiment shown) you know that I store electrical energy, and I can use my stored energy at any future time if the insulation of my jar is good. Thus I have converted a small store into heat and light. (Experiment shown.) Again, I can use this store at any time to give itself out at a distant place. This is a very small store. But now observe that my thermopile has been working for nearly an hour, and some time ago it had filled these two test tubes with oxygen and hydrogen. With these two gases I can produce, as you all know, a most intense heat. You all know that this lime light is produced simply through my having such a store in these iron bottles which you see before you. Remember that these gases might be kept stored up for as long as we like, and that if a windmill worked a magneto-electric machine it could produce such a store working now fast, now slow. Well, but I can take this store and convert it again into electricity with very little loss. You will see that it can produce an electric current if we have two similar metal plates in the positions you see them in, and if I connect these metal plates through the galvanometer (experiment shown), you have there evidence of a current, this deflection of the needle of the galvanometer. This current will continue to flow, and the electric energy will continue to be given out until all the store of gas disappears.

Instead of using that weak thermopile, suppose I had used this strong current produced by the outside engine, you see how much more rapidly my store is formed. (Experiment shown, in which

the gases rapidly formed were used to produce an oxy-hydrogen lime light.) I grant that the elaboration of this gas battery into a compact generator, sufficiently powerful to produce very large effects, is a problem of some expense for future workers; but give it to any electrician, and make it worth his while, and I believe that such a generator might be constructed in a very short time.

To introduce the next part of my subject, let me ask—Can anybody hear the sound by a puff of air as it passes through the hole in this cardboard disc? (Experiment made.) Nobody heard it, or the difference produced when the air was stopped by the cardboard. But suppose I repeat this operation several hundred times per second, you can all hear the powerful musical note given out. (Experiment.) You see, then, that the rapid recurrence of effects may be very sensible to us, although one such effect may not be sensible. In the same way, if light streamed through one of the holes in this brass disc into your eyes, it would not produce a very striking effect; whereas Professor Tyndall says that when such a disc as this was rotating so as to let the light falling on his eyes be very rapidly intermittent, he experienced the most extraordinary sensations. Again, if I very much alter the magnetic field in this telephone, by bringing a powerful magnet near it, with great care in listening I hear the faintest sigh, due to the diaphragm settling itself into a new position, its vibrations dying away as it does so; and if I brought a small magnet near, I should hear nothing. And yet the change of magnetism which produces the loud telephonic effects which we listen to is almost infinitely smaller. Why is this? It is due to the rapid recurrence of the effects. Now you are all aware of the importance of the telephone as a method of communication; I believe that a much greater importance is in store for it as a laboratory appliance.

Here is a selenium cell through which I can pass a current of electricity from this large battery, which also passes through these two telephones, which I can hold to my ears. When light falls on this selenium its electric resistance is diminished,and a stronger current passes. This is a property discovered by Mr. Willoughby Smith. Now I cannot hear in the telephone any effect produced by letting light suddenly fall on the selenium. The difference of current produced in the very case before you is only one two-thousandth of a weber. But if I rotate this brass disc so as to make the light fall with intermittence several hundreds of times in a second on the selenium, I can distinctly hear a musical sound. This is what Professor Bell has been exhibiting lately, and it constitutes the principle of the photophone. Now to give you an idea of the new ground which the use of the principle of recurrence is opening up in laboratory work, let me speak of an experiment which is now in progress. Professor Bell spoke in his lecture of having tried to stop the intermittent rays of light of this instrument by a sheet of ebonite like this, but he found that there was still a very faint sound from the telephones. Well, it occurred to Professor Ayrton and myself that if ebonite is transparent to some kind of invisible radiation, then in all probability it is capable of refracting such invisible rays. So we obtained this ebonite lens, and two prisms, and tried. We thought the lens would bring the invisible rays to a focus, but as our lens was not mounted, so that we could move it parallel to itself, and as the rays are, of course, quite invisible, so that our eyes cannot help us to focus the ebonite lens, we did not succeed in this very delicate experiment, which the following experiment, however, shows, must ultimately be successful. Next we placed the cell at A in this diagram (Fig. 7), and found that it gave out no sound, being beyond the range of the beam of intermittent light. We placed the prism in the position B, in which you see it, and, to our great satisfaction, a sound was heard. You must remember that this sound, and any sound obtained from light that had passed through ebonite, was exceedingly feeble. The person who listened was in another room, so as not to be in any way influenced by what he saw, and his preciseness in detecting sound was determined by another experimenter putting his hand in the beam of light and taking it away again. So that there could be no doubt as to the origin of the faint sounds heard. Well, the prism caused the light to bend round,

and now the question was as to how much bending it produced. We provided two pieces of zinc plate, with slits cut in them. You all understand, I hope, that the most advanced physicists regard a metal as a perfectly opaque body, even to invisible rays, so that rays can only pass through the slit in our zinc. Well, we placed the slit in the zinc within a short distance of the edge of the prism, and found a position in which the rays, passing through the slit, still reached the selenium. The sound was now very faint. Then we searched on the selenium

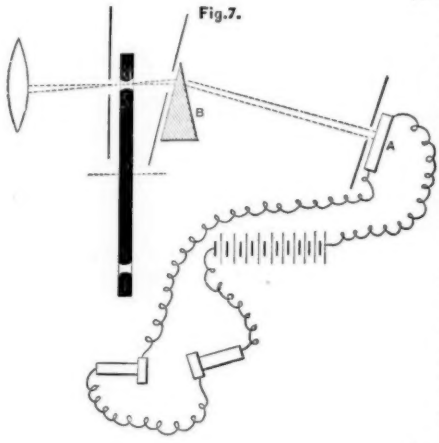


Fig.7.

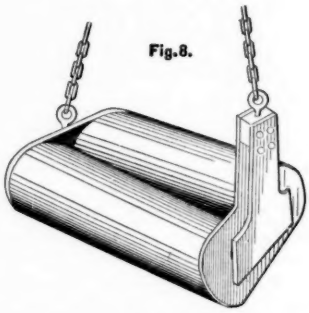
with the edge of our second piece of zinc, to find what region of the cell might be covered without destroying the sound. We found that region, and placed our second slit there. Rays passing through the first slit were now passing through the second slit. If either was changed in position, the sound died away instantaneously. Thus, there could be no doubt of the fact that ebonite refracted that invisible beam, about which nothing else is as yet known. If our slits had been very narrow we could have measured accurately the index of refraction, but with narrow slits the sounds were too faint to be heard in the center of London; so all that we can say at present is, that ebonite certainly refracts light, and its index of refraction is, speaking quite roughly, 1.7. Now, it is somewhat curious that this was the rough measurement which we made. For Clerk Maxwell's theory, that light is propagated through space like an electro-magnetic disturbance, requires the square of the index of refraction, for light of very low refrangibility to be equal to the electric specific inductive capacity of the substance, and it has long been known that this electric constant for ebonite varies from 2.2 to 3 5 in different specimens. The square of 1.7 is 2.89. Thus, you see that this curious following out of our first idea has led to a further backing up of Clerk Maxwell's electro-magnetic theory of light. This and other investigations which we are now proceeding with, illustrate two important things, namely—the principle of recurrent effects in the use of the telephone, has opened up a new path into unexplored nature; and, secondly, the laboratory worker sees before him a hundred interesting phenomena, which ought to be investigated at once, and which he cannot take up unless he gets more apparatus, more money, and more observing eyes and working hands.

About two years ago, it struck Professor Ayrton and myself, when thinking how very faint musical sounds are heard distinctly from the telephone in spite of loud noises in the neighborhood, that there was an application of this principle of recurrent effects of far more practical importance than any other, namely, in the use of musical notes for coast warnings in thick weather.* You will say that fog bells and horns are an old story, and that they have not been particularly successful, but our scheme was of a somewhat different kind. In northern Japan, where fogs are the rule and not the exception, which they are in England, and where changing currents of more than six knots are common off many dangerous parts of the coasts, shipmasters are very much in the habit of using their steam whistles, listening for the echo from the steep coasts, and judging from the interval of elapsed time what is their distance from the coast, and what is their

* Since the reading of this paper, my attention has been drawn to a letter in the *Engineer*, of Jan. 28th, 1876, from Mr. H. T. Humphreys, who there suggests the use of submarine sirens as coast warnings. Since the idea struck Mr. Ayrton and myself, we have been wondering how it escaped attention so long. We now wonder why the lighthouse authorities have made no efforts in the last five years to carry Mr. Humphreys' idea into effect.

position. But they find that on many foggy days they can, and on other foggy days they cannot use this method, because they may hear no echo, although quite near the coast. Now, it seems to be forgotton by everybody that there is a medium of communication with a distant ship, namely, the water, which is not at all influenced by changes in the weather. At some twenty or thirty feet below the surface there is an almost perfect calm, although there may be large waves at the surface. Suppose a large water-siren like this (experiment shown) is working at as great a depth as is available, off a dangerons coast, the sound it gives out is transmitted so as to be heard at exceedingly great distances by an ear pressed against a strip of wood or metal dipping into the water. If the strip is connected with a much larger wooden or metallic surface in the water, the sound is heard much more distinctly. Now, the sides of a ship form a very large collecting surface, and at the distance of several miles from such a water siren as might be constructed, we feel quite sure that, above the noise of engines and flapping sails, above the far more troublesome noise of waves striking the ship's side, the musical note of the distant siren would be heard giving warning of a dangerous neighborhood. I have no time now to tell you of the small experiments we have made in this direction. This electric bell sounds only very faintly when in water, and yet we have been able to hear it at the distance of sixty feet along a trough of water in a place filled with the noise of much heavy machinery. We took this water siren to Hastings for a trial in ordinary boats, but the weather was too rough at the time for boats to go out; and, therefore, the experiment had to be postponed. We have constructed the arrangement shown full size in this diagram, in which currents of electricity are sent from a distance sufficiently rapidly intermittent through this electro magnet to give the natural period of vibration to this armature when in water (Fig. 8). Whether this will prove successful or not we do not know, but we feel sure that the idea is to be carried out electrically, the source of sound being a motor worked by a generator on the nearest coast. In considering this problem, you must remember that Messrs. Colladon and Sturm heard distinctly the sound of a bell struck under water at the distance of nearly nine miles, the sound being communicated by the water of Lake Geneva.

Fig. 8.



An electro-magnet, with vibrating armature, giving out loud musical note.

Another application of the principle of recurrent effects, which may, indeed, be regarded as the earliest of such applications, is this multiple telegraph of Mr. Elisha Gray, which my friend Mr. Graham has been kind enough to put in working order, so that it may be worked from this table to the telephones hanging against that wall. About this telegraph, which allows a great number of messages to be sent through an ordinary telegraph wire at the same time, Sir William Thomson wrote to me in terms of high eulogium when he first examined it at Philadelphia. At present I believe that the quadruplex system is more favorably looked upon because it has succeeded better in practice, but I am inclined to think that in the distant future it may possibly have enormous development.

In this paper I wish I could bring in, as illustrations of the few great principles which are really the important factors in the future development of electrical appliances, the microphone and all the instruments which have been derived from it, but even to refer to them would take far too much time. I would end by speaking of two appliances which are of quite a different species, namely, Mr. Edward Bright's method of de-electrifying woolen yarn, and of a contrivance for seeing by electricity. In the manufacture, the woolen yarn becomes electrified by

friction, and has hitherto lost its electricity very slowly, requiring to be stored for many months in damp cellars before it got rid of its electricity. Until lately, nobody seems to have suspected that it was electricity which caused the fibres to stick out on all sides of the yarn instead of staying in an interlaced condition. It was found to occur most in dry weather, and was vaguely put down by Englishmen to "the weather." So very annoying was this in a dry climate, that although Bradford men and Bradford machines were taken to America, only two months in the year could really be devoted to the manufacture. Now, we have here some wool staple in the air which is being electrified by this plate machine. You see how the fibers repel one another and remain in this state. You observe, however, that these other fibers we try vainly to electrify because they are in a partial vacuum, and electricity escapes from them as rapidly as it is formed. I will allow air to enter this air-pump receiver, and now, when the machine is worked, you see (experiment shown) that these fibers retain their electricity. The principle that a partial vacuum is very conductive has long been known to electricians, but the remarkable saving in woolen manufacture, effected by applying a knowledge of the principle, was left for Mr. Bright. Mr. Bright's plan of operations is to have chambers where partial vacua may be produced. He wheels large trucks of electrified bobbins of yarn into these chambers, and takes them out very soon, unelectrified, thus performing, in a few minutes, an operation that used to be badly performed, in a costly manner, in half a year. Can we doubt that, when boys obtain, in all elementary schools, a little knowledge of electricity, there will be rapid additions to the number of electrical appliances?

And now let me come to the last of the developments of electrical appliances, still perhaps somewhat in the future. A picture in *Punch* of an aged couple at home seeing on their drawing-room wall an image of their children playing lawn-tennis out in India, and of their conversing with some of them by telephone, first led Mr. Ayrton and myself to think of this matter. We showed that it was feasible, in a letter to *Nature*, and in the *Times* about a year ago. The feasibility of the method described by us was doubted, and we therefore proved it at a meeting of the Physical Society four weeks ago. I mean to put it before you in a slightly different form. Suppose that place is York, and this is London. I have a little selenium cell at York on a certain part of this picture, and at London I can throw at a corresponding place on this screen a square of light; and suppose that the illumination of this square is governed by a little movable shutter which is attached to the needle of a galvanometer. Now when light falls on the selenium at York, an immediate change occurs in it, so that more current flows to London, and this opens the shutter. The London square is then bright, when the York selenium is in bright illumination. When the York selenium is in shade or darkness, you see that the London square is in corresponding shade or darkness. (Experiment shown.) Now suppose that we form an image of this girl with her skipping rope at York, and cause a selenium cell at York to travel across her image, and suppose that this mirror at London moves so as to cause the illumination which passes the shutter to traverse this London screen isochronously—an operation performed in several telegraph instruments. Then whenever this cell reaches a dark, or shady, or bright place in the image at York, there will be darkness, or shade, or brightness at the corresponding place in London. And now suppose that this motion is effected rapidly enough, you are all aware that if the shutter is only quick enough in its answering motions, the image of the part of the screen at York traversed by the cell will be faithfully reproduced, and will remain on the retina at London as a distinct picture in black, and gray, and white, just like a photograph. With then, perhaps, forty such cells as this, all moving in the way spoken of, or a smaller number rotating on a radial arm, it would actually be possible to show at London, not merely an image of a girl at York, but an image of a girl skipping. You will, perhaps, understand better this principle from the model. Here is a path of black and white spaces at York, over which this selenium cell is made to travel. We have continued the images to the paper above, simply to let you know when the cell is in the image of a

dark place, and when it is in the image of a bright place, so that you may be able to say whether there is a faithful reproduction at London. These two frames are really tied together by this long string to make them move isochronously. In practice, I need hardly say that this function will be performed in another but quite as feasible a manner.

The cell at York is in a black part of the picture; you observe no light on that part of the screen in London. The cell at York is in a bright part of the picture; the corresponding part of the screen at London is bright. And so we find that, as the cell goes successively through dark and bright places, so the corresponding parts of the screen at London are made dark and bright. (Experiment shown.) Our shutter is not yet sufficiently deadbeat for us to make this motion rapidly.

I had hoped to be able to show you to-night the development of this method, by using what we have called the Japanese-mirror principle. We have shown that the most minute effects on the backs of metal mirrors, effects quite invisible when examining the polished surface of the mirror, are very visible in the reflection of a divergent beam of light. Such effects, we believe, we can produce by electro-magnets arranged radially behind a circular mirror and rotating with it. This radial arrangement of magnets will move synchronously with a radial arrangement of corresponding cells. The principle, however, is exactly the same as that shown by this model, only we know that the change of curvature at a point in a mirror will obey changes of magnetic effects more rapidly than this shutter does.

I had hoped to be able to present to you the scheme which Mr. Shelford Bidwell has proved to be feasible, of reproducing in shaded lines on paper, by electro-chemical decomposition, a picture of a distant stationary object. I understand, however, that Mr. Bidwell has been asked to read a paper here, when he will exhibit the model he has made.

Fig.9.

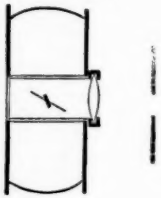
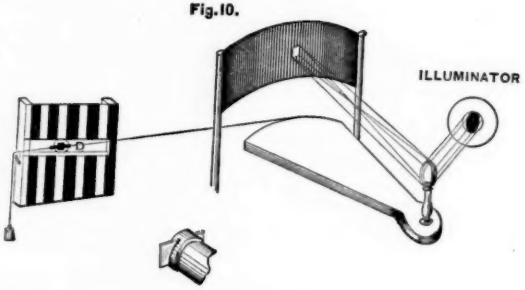


Fig.10.



In my paper read here a year ago it was the importance of giving artisans facilities for obtaining practically exact knowledge in science that I especially laid stress on. To-night I have desired, first, to show what benefits our country would receive from an exact knowledge of electrical magnitudes, and of the fundamental laws of electricity being more widely disseminated, and, second, how the principle of recurrent effects may be employed to assist our senses.

At a recent meeting of the California Academy of Sciences, Dr. H. Gibbons said that since he put petroleum on the trees in his garden they have grown better and faster than ever before, and given better roses than before. The petroleum seems to kill the scale insect. The handsomest rose he exhibited was from a bush which looked nearly dead a short time before. The petroleum was mixed with castor oil. It is applied sparingly, and great care taken that it does not run down the roots. Perhaps in a crude state the petroleum would be bad, even on the stalks; but mixed with the castor oil it appears to be advantageous to the plant.

EQUILIBRIUM OF PULVERULENT BODIES.

By PROFESSOR J. BOUSSIN, Esq.

From Foreign Abstracts of Institution of Civil Engineers.

PULVERULENT bodies, such as sand or earth recently turned up, whose particles in sliding on one another experience no resistance except that arising from their mutual friction, are susceptible of many distinct modes of equilibrium.

The only one which has hitherto been studied is the limiting case when the mass is on the point of motion, and when the friction of the particles attains its maximum. Formulæ relating to this state were obtained as early as 1856 by Rankine, and subsequently by Levy and others.

But there is another kind of equilibrium equally important to consider, viz., that which is produced in the interior of a pulverulent mass confined by a wall sufficiently firm to prevent any disturbance of the particles. In this state the friction of the various strata on each other is generally less than in the other; just as, in a solid body in elastic equilibrium, the strains remain always less than those which would produce permanent alteration of its structure; the particles are then retained in position by their mutual actions less forcibly than if the wall were to give under their pressure, and they exercise upon it a thrust greater than the formulæ of Rankine and Levy give. This is the kind of equilibrium studied in the memoir. It is called "elastic equilibrium" because the pressures induced depend on certain small deformations, which the mass, supposed at first homogeneous and without weight, would undergo if it became, as it really is, heavy.

The bodies in question occupy a position midway between solids and fluids; for whilst solids and fluids, submitted to pressures varying from zero to considerable intensities, oppose to any given deformation a constant force—finite for the first, zero for the second—pulverulent bodies resist change of form with an energy so much the greater as the mean pressure to which they are subjected is greater; fluids almost when not compressed, they become rigid like solids under pressure. Their co-efficient of rigidity (*co-efficient d'élasticité de glissement*—Lamé's μ), instead of being constant, as in the case of solids, or zero, as in the case of fluids, appears to be proportional to the meam pressure p to which they are exposed. The author deduces this from the expressions which represent in isotropic bodies the mean of the principal elastic forces (*i. e.* the mean pressure p with its sign changed) and the differences of these forces, in terms of the three principal deformations, δ_1, δ_2, δ_3. Retaining in all the results the terms of two dimensions in δ_1, δ_2, δ_3, and expressing that the matter under consideration ceases, for finite values of δ_1, δ_2, δ_3, to be subject to the action of tangential elastic forces when p is zero, he finds that the normal and tangential components, N_1, N_2, N_3, T_1, T_2, T_3 (according to Lame's notation) of the pressure, per unit of area, on three elementary planes perpendicular to the axes, have the values (provided they do not exceed certain limits)

$$N_1 = -p\left(1-2m\frac{du}{dx}\right),$$

$$T_1 = pm\left(\frac{dv}{dz}+\frac{dw}{dy}\right), \quad \&c.,$$

where m is a constant positive co-efficient of considerable magnitude, and where u, v, w designate the molecular displacements parallel to the axes of x, y, z. The same analysis proves that the cubic expansion (dilatation) may be neglected in comparison with the three linear expansions to whose algebraic sum it is sensibly equal, or that the condition of incompressibility $\frac{du}{dx}+\frac{dv}{dy}+\frac{dw}{dz}=0$ holds. The remaining three equations between the N's and T's necessary for determining n, v, w and p are

$$\frac{dN_1}{dx}+\frac{dT_3}{dy}+\frac{dT_2}{dz}+\rho X=0,$$

$$\frac{dT_3}{dx}+\frac{dN_2}{dy}+\frac{dT_1}{dz}+\rho Y=0,$$

$$\frac{dT_2}{dx}+\frac{dT_1}{dy}+\frac{dN_3}{dz}+\rho Z=0,$$

where ρ is the density of the mass, and X, Y, Z the components of gravity parallel to the axes.

The special conditions existing bounding surfaces are as follows: at the

1st. At free surfaces, the effective pressure on the outside layer is zero; for the atmospheric pressure around each grain does not influence the mutual action between it and contiguous grains.

2nd. At fixed boundaries (such as the posterior faces of retaining walls) which are sufficiently rough—as they generally are—to prevent motion in the particles adjacent to them, u, v, and w vanish; and in the case of a surface infinitely smooth, the normal component of the displacement and the tangential components of the pressures are zero.

The integrations of the equations are easy when the mass—of indefinite extent in all other directions—is limited above by a plane making an angle ω with the horizon. The states of equlibrium of a pulverulent mass bounded in this way are infinite in number, and belong to one of two series, according to the values given to two of the arbitrary constants, c, c', introduced in the integration.

Any system of parallel material straight lines, situated in a vertical plane perpendicular to that of the upper slope, changes, through the small deformations it undergoes, into a family of concentric conic sections, similar and similarly situated, the axes of which bisect the four angles which are formed by a vertical straight line and the line of intersection of the upper surface of the mass with the plane aforesaid. These conic sections become circles of very large radius for straight lines parallel to the slope, and are reduced to parallel straight lines when one of the arbitrary constants $c=0$.

There are, in particular, two systems of equidistant and parallel straight lines, originally at right angles and inclined, the one to the vertical, and the other to the horizontal, at an angle ε, which after deformation of the mass remain straight, parallel, and unchanged in length, but are turned with respect to one another through a small angle $\frac{\sin\omega}{m\cos(\omega-2\varepsilon)}$. The squares which they originally formed by their intersections become diamonds, and the ultimate form of the mass may be arrived at by supposing it originally divided into indefinitely thin layers, inclined at an angle ε to the vertical, which slide in their respective planes in such a manner, that if one be considered as fixed, any other situated at a distance D in front of it will be displaced downwards by a quantity $\frac{D\sin\omega}{m\cos(\omega-2\varepsilon)}$. The case in which $c=0$ comprises an infinite number of modes of equilibrium, since there still remains the arbitrary constant c', is the most interesting, as it is the only one in which, by properly determining c', the conditions existing at a boundary, whether smooth or rough, are found to hold throughout the extent of any plane cutting the upper slope in a horizontal straight line—in other words, inclined to the vertical at the angle ε; and it is the only one in which the particles in this plane remain immovable during the deformation of the mass. Hence equilibrium will still subsist, if the material on one side of the plane be replaced by a retaining wall having this plane for its posterior face. This is naturally the mode of equilibrium produced where such a wall really exists, and it will be the same for two directions of the wall at right angles to each other.

When, therefore, the posterior face of a retaining wall is rough, and inclined to the vertical at an angle ε, the settlement of the mass takes place by displacement parallel to the face, and is, as already stated, equal, for any particle, to the product of its distance from the face by the constant factor $\frac{\sin\omega}{m\cos(\omega-2\varepsilon)}$.

Admitting the existence of the special condition set forth above at the surface of the wall, the pressure R on an unit of area at a depth L (measuring along the face) and the angle Φ_1 which its line of action makes with the prolongation of the normal thereto, toward the interior of the wall, are given by

$$R=K\rho gL \quad \tan\Phi_1=\frac{\sin\omega}{\cos(\omega-2\varepsilon)},$$

where $K=\frac{\cos(\omega-\varepsilon)\sin\omega}{\cos 2(\omega-\varepsilon)\sin\Phi_1}$.

If, on the contrary, the wall were mathematically smooth, the values of $\tan\Phi_1$ and K would be 0 and $\frac{\sin\varepsilon}{\tan(\varepsilon-\omega)}$.

The total pressure P on an unit of

width of the wall is $\frac{1}{2}K\rho g L^2$ (where K has one of the values given above) and the point of application of its resultant, whose direction is parallel to R's, is at a depth $\frac{2}{3}$ L (L being in this case the total height of the wall measured along the face $= \frac{h}{\cos \varepsilon}$).

In obtaining these results the limit of elasticity of the matter has not been taken into consideration. Now, just as in solving the problem of the equilibrium of a perfectly elastic solid, under the action of given forces, it is necessary to express that the greatest deformation at any point must be less than that which will cause a permanent set, so it is necessary, in this case, to express that the greatest linear extension at different points of the mass must not exceed that limit which it cannot surpass without danger of disruption (*éboulement*).

Pulverulent bodies, being without cohesion, are incapable of transmitting tensions, whence it follows, by the analysis, that the greatest linear extension δ_1, must be less than the ratio $\frac{1}{2m}$. The limit of elasticity, being thus less than $\frac{1}{2m}$, can always be expressed in the form $\frac{\sin \Phi}{2m}$, where Φ denotes an angle (lying between 0 and $\frac{\pi}{2}$ generally) whose value for each particular kind of matter must be determined by experience. This angle may be called the angle of internal friction of the mass.

It therefore appears that the only states of equilibrium possible are those in which the condition $p>0$ and $\delta_1 > \frac{\sin \Phi}{2m}$, expressing the imperfect elasticity of the matter, are satisfied.

A first consequence of the imposition of these new conditions is to make the constant c vanish, *i.e.*, to reduce all the possible modes of equilibrium of an indefinite mass to those which can subsist in a mass bounded by a plane wall, and further, such modes of equilibrium, which then depend on a single parameter ε, say, are shown to be possible only when $\cos^2(\omega - 2\varepsilon) \geqslant \frac{\sin^2 \omega}{\sin^2 \Phi}$.

Their number, unlimited so as long the inclination of the upper slope to the horizon is zero, becomes more and more restricted as that inclination becomes greater, and when $\omega = \Phi$ they are reduced to one only; when ω exceeds Φ equilibrium becomes impossible. Thus the theory explains the impossibility of a pulverulent mass existing with a slope whose inclination exceeds the angle of friction of the matter of which it is composed.

The formulæ already obtained depend on special conditions, and relate to the case of a mass, originally without weight and free from pressure, which, on becoming heavy, takes a new state of equilibrium without the layer next the retaining wall having moved, if the wall be rough, or having moved out of its own plane, if it be smooth. Practically, however, in forming such a mass against a rough immovable wall already built, the particles contiguous to the wall only remain stationary so long as they are but slightly compressed. But the addition of successive quantities of earth or sand subjects them to increasing pressure, and causes them to move through finite distances, the result being an entirely different state of equilibrium. This state is that in which the internal stability of the mass is greatest, or in which the maximum extension δ_1 has at each point its least value compatible with the degree of resistance of the wall. The analysis shows that δ_1 attains its minimum value $\pm \frac{\sin \omega}{2m}$ when $\varepsilon = \frac{\omega}{2}$. This, then, is the value of ε which corresponds to the most stable state of internal equilibrium.

If, however, the wall is not sufficiently firm to allow of the mass attaining its maximum stability, the state of equilibrium produced is that in which the whole resistance of the wall is utilized. In these cases the value of the parameter δ, which defines the mode of equilibrium, is determined by the relation

$$\tan 2\varepsilon = \frac{\cos 2\varepsilon_1 \cos 2(\omega - \varepsilon) - \cos 2\omega \cos 2(\varepsilon_1 - \varepsilon)}{\sin 2\varepsilon_1 \cos 2(\omega - \varepsilon) - \sin 2\omega \cos 2(\varepsilon_1 - \varepsilon)}.$$

Whether the stability of the mass attain its maximum or not, the direction and intensity of the resultant pressure on a wall inclined at an angle ε_1 to the vertical are given by $P = \frac{1}{2}K\rho g L^2$,

where $$K=\frac{\sin\omega\cos(\omega-\varepsilon_1)\cos 2(\varepsilon_1-\varepsilon)}{\cos 2(\omega-\varepsilon)\sin\Phi_1}$$

$$\tan\left(\Phi_1+\varepsilon_1-\varepsilon+\frac{\pi}{4}\right)=\frac{\tan\left(\varepsilon_1-\varepsilon+\frac{\pi}{4}\right)}{\tan^2\left(\frac{\pi}{4}-\omega+\varepsilon\right)},$$

by substituting for ε its proper value.

All these modes of equilibrium are stable; for the wall may be supposed without weight, but held in position by an externally applied force, and by the pressure of the mass which it supports. If then the wall were to move towards or from the mass, the pressure of the latter upon it would increase or diminish, and this would exceed or be exceeded by the external force, so that the wall would tend to return to its original position.

Hence it is not necessary to make the thickness of a retaining wall greater than will enable it to support a pressure slightly exceeding that which corresponds to the least stable state of equilibrium.

Assuming the posterior face of the wall to be vertical (in which case the direction of the resultant pressure will be parallel to the upper slope) and Φ to be $= 45°$, the following table gives the greatest and least numerical values of K for different values of ω.

TABLE I.

	$\omega=0°$,	$\pm10°$,	$\pm20°$,	$\pm30°$,	$\pm40°$,	$\pm45°$
Greatest value of K	.1716,	.1765,	.1935,	.2320,	.3404,	.7071
Least " " "	1,	.9848,	.9397,	.8660,	.7660,	.7071

The equilibrium of such a mass will therefore be stable provided the wall can support a pressure, applied at one-third of its height, parallel to the upper slope, and slightly greater than $\frac{1}{2}K\rho g L^2$, where K has the values .1716, &c.; but in order that the most stable state of equilibrium may be realized, the values of K must be taken from the lower line in the table.

For example, a retaining wall of rectangular cross section would tend to turn about the front edge.

In order to determine the condition of equilibrium it is necessary to equate the moment of the weight of the wall about this edge to the moment of the pressure of the mass (P) about the same axis.

Calling ρ' the density of the wall, b its breadth, and h its height, the weight of an unit of length will be expressed by $\rho' g h b$, and its moment about M_1 by $\frac{1}{2}\rho' g b^2 h$. The point of application of the pressure P will be at one-third the height of the wall, and the direction of its line of action parallel to the upper slope, its moment about the turning edge is therefore

$$\tfrac{1}{2}\rho g h^2 K(\tfrac{1}{3}h\cos\omega - b\sin\omega).$$

By equating these expressions, and reducing, the value of the ratio $\frac{b}{h}$ is found to be

$$=\tfrac{2}{3}\times\frac{1}{\tan\omega+\sqrt{\tan^2\omega+\frac{4\rho'}{3\rho}\frac{1}{K\cos\omega}}}.$$

1. Suppose the thickness of the wall is to be just sufficient to insure equilibrium, and assume for ρ' the value $\frac{3}{2}\rho$, which will not in general be far from the truth, then, substituting for K its numerical value from the upper line of Table I., the following results are obtained for

$$\frac{b}{h}\left\{\begin{matrix}\text{(minimum}\\\text{stability)}\end{matrix}\right\}$$

$\omega=$	0°	10°	20°	30°	40°	45°
	.1953	.1866	.1802	.1761	.1786	.2060

2. If, on the contrary, b is to be such that the most stable mode of equilibrium may subsist, the value of K must be taken from the lower line in the table, and for

$$\frac{b}{h}\left\{\begin{matrix}\text{(maximum}\\\text{stability)}\end{matrix}\right\}$$

$\omega=$	0°	10°	20°	30°	40°	45°
	.4714	.4107	.3486	.2887	.2325	.2060

A consideration of these figures proves that the practical rule of making the thickness of a retaining wall equal to one-third of its height insures in general sufficient stability.

The author then proceeds to examine the condition of the mass when disruption commences, and deduces the equations relative thereto. He also obtains in polar co-ordinates the equations applicable to the limiting state of equilibrium of a mass, plastic or pulverulent, submitted to pressures very great in comparison with its weight.

ELECTRIC RAILWAYS.

From "The Builder."

To predict that the locomotive engine will have its day—that, like some of the gigantic forms of the geological series it will attain its widest development only to fade away and die—would be a hazardous prediction. It would not, however, be more bold than was the original prediction of George Stephenson, that he would make a steam coach that should run at twenty miles an hour. That anticipation, indeed, was thought to be so rash that it could not be entertained by any sane and well-balanced mind. And yet, within ten or fifteen years of its utterance, Brunel was designing engines to run at 100 miles an hour; and made them to go, and steadily worked a portion of the traffic of the Great Western Railway, at a running speed, over more than twenty miles of line, of seventy miles an hour, which is about the speed of the great senegal swift on the wing.

So rapid and so successful has been the growth of the locomotive engine, that its admirers may well hold that it promises to be the motor power of the future, as well as of the present. And there is no doubt that immense advantages attend on the method which has wrought such a revolution in our means of transport. But the locomotive has certain great disadvantages with which to contend. The mode of thus applying power is extremely costly. The actual resistance of the engine ranges from a weight equal to that of the rest of the train to about a fifth of that proportion. To move that weight is not only costly in proportion to the ratio between train and engine, but is so in a much higher proportion; as the friction of the automatic engine is much greater, per ton, than is that of the propelled train. Allowing equal figures for atmospheric resistance, the constant for the friction of the engine is usually calculated at about double of that for the train. But we have a more exact mode of ascertaining the cost of locomotive power, and that is one as to which it is very remarkable that it has been hitherto so far left out of sight. On the Blackwall railway, at the time when it was worked by ropes, observations were made as to the power absorbed by the loaded, and by the unloaded rope, the difference between the two being that due to the weight of the train. This was only 21 per cent. of the whole. The cost of working per ton per mile, according to data given by Mr. Robert Stephenson, was 0.1875d. This is less than the cost of working any railway in England in the year 1879, with the one exception of the Manchester, Sheffield and Lincolnshire line, in which the cost is at the minimum, not owing to engineering consideration, but because the traffic is so much more equal in both directions than is the case in any of the great trunk lines leading to the metropolis. The great source of waste, the return of empty wagons, is thus avoided. As closely as we can calculate, the average cost of railway transport in the United Kingdom in 1879 was a little over one-fifth of a penny per ton mile of loaded train, not including the weight of the engine and tender. But the Blackwall cost, for moving loaded trains alone (the cost of the apparatus being deducted) was 0.4d. That is the cost of what was anticipated to be a very costly mode of propulsion (although it was in the first place thought to be preferable to the use of locomotives). We find that the consumption of power by the stationary apparatus was about four-fifths of the whole power exerted. And we are thus led to the conclusion that four-fifths of the power of the locomotive is consumed in the propulsion of itself and of its tender.

A bit of positive experience such as this adds great point to the value of any attempt to substitute for the locomotive a means of propulsion that has a fixed point of resistance. The attempt was made, years ago, by the projectors of the atmospheric railway. Some of the first engineers of the day—Isambard Kingdom Brunel in this country, and Eugene Flachat in France—entertained a high opinion of the feasibility of this plan; and not only so, but backed their

opinions very heavily by their purses. And it should be more generally known than is the case that it was not to the mechanical difficulties of the problem, great as they admittedly were, that the final abandonment of the scheme was due. A speed of sixty miles per hour was attained on the atmospheric railway between London and the Croydon; and the Dublin and Dalkey Railway was regularly worked on this system for many months. The real cause of failure was the rapid entrance of the terrestrial heat into the exhausted tube, thus raising the resistance of the rarefied air to a tension almost equal to that of the external atmosphere. Thus, the stationary engines on the South Devon Railway were actually pumping heat out of the earth. They became nearly red hot in the process, which was like that of baling water by a sieve. Nor is it probable that this physical obstacle to atmospheric propulsion against an artificial vacuum can ever be successfully overcome.

Messrs. Siemens have lost no time in endeavoring to apply the greatest discovery of modern times—probably the most important physical discovery ever made, that of dynamo electricity—to locomotion. In our opinion, the attempt deserves the most careful and patient attention. The difficulties to be overcome, as in the former case, are not so much mechanical as physical. That the former obstacles can be vanquished, Messrs. Siemens will say, is no longer matter of doubt. They can point to the actual speed of some ten miles an hour attained by their electric locomotive and its miniature train in the grounds of the Crystal Palace. The main difficulty here—and we are not among those who regard it as insuperable—is that of conduction. This is *the* great question, on which, as we have more than once intimated, the future of the industry of mankind depends. It here presents a new "case" to the student. It is a difficulty which opposed the introduction of the electric light, and which has been, already, to a great extent removed, as far as it opposed an obstacle to science. It is the primary question of electric conduction. The working of a line of 800 yards in length does not give much information as to the mode in which a system that may work admirably for such a distance, can be extended for a distance of 300 miles.

In the experiment at Sydenham the motor power is supplied by a stationary engine of eight-horse power nominal, which drives, in the ordinary mode, a dynamo-electric machine. The electric current induced is conducted along a rail laid in the middle of the track on which the trains travel, which is partially insulated by being laid on wooden blocks. The return current passes through the exterior, or bearing, rail. The locomotive is a Siemens dynamo-electric machine, mounted as a propeller, and as acting as a sort of counterpart to the fixed dynamo-electric motor. The current produced by the latter, and sent into the central rail, is taken up by brushes of iron wires attached to the locomotive; and thus causes the appropriate part of that apparatus to revolve. Having thus done its work, the current escapes through the metal wheels of the truck to the exterior rail.

It is evident that this is a bold and beautiful application of the principle of the electric telegraph. Correspondence of action between two portions of apparatus, placed in electric communication, is effected in each case. In one, motion is communicated by one stationary machine to another. In the other, motion is communicated from a stationary to a corresponding movable engine. The fact that a much larger development of energy is applied in one case than in the other does not affect the principle. Nor does it, so far as the dynamo-motors are concerned, affect the promise of success. We do not see why the same principle which moves a ray of light, by an impulse sent through 3,000 miles of cable, should not be applied to the movement of a train of 1,000 tons, so far as the mere reciprocal action of the dynamo-motor is concerned. The knot of the question does not lie there. It is concealed in the center rail. It regards the transmissibility of the power. As to this, a little line of 300 yards tells us little. The point which most disappoints us is, that so long a time has now elapsed since Sir W. Thomson and Dr. Siemens both expressed their opinion as to the transmissibility of enormous doses of electric force through conductors of a certain magnitude, without more having

been said or done on the subject. It is with this question of transmissibility of power that the industry of the future is bound up. So long as distance is sharply limited in this respect, coal will continue to be the main source of mechanical power. It is a costly source, and it is one of which the cost depends greatly on locality. If, for example, ten miles should prove to be the extreme distance for which 40-horse power or 50-horse power of energy can be transmitted electrically without enormous loss, coal will for the present hold its own. If the question should be answered in the opposite sense, the reign of King Coal is not more assured than is that of certain potentates of more ancient dynastic rule, although of less remote pedigree.

THE GUN QUESTION.

From "The Engineer."

THE information recently supplied to the House by Mr. Trevelyan, and the questions asked by Mr. W. H. Smith, have naturally brought up again the question of the rival systems of construction of ordnance. It is urged with much force that we need a large supply of powerful breech-loading guns, and that it is desirable to have it with as little delay as possible. If, then, a really good and powerful new type gun can be obtained without doubt at once, it seems wise to take the responsibility of immediately giving an order. This appears to be the case. The Elswick firm, who have really taken the lead in the development of new type guns, have actually had their ordnance under Government trial for the last two years. They have fired their guns with an enormous amount of stored-up work in them, and the trial has been very successful. Does it not appear reasonable and fair to them to begin by ordering guns from them? We ask this question, not as a preliminary to contradiction, because we do not see cause to contradict it. We think, if a certain number of guns are immediately wanted, it is reasonable and right to give the preference to those who stand in the position held by Elswick. This, however, is not the last word to be spoken on the question. While we believe that in the investigation of the problem how to burn powder to the best advantage, England has been well to the front, it has happened that the conclusions we arrived at were not, on the whole, favorable to our own service guns. In the development of length our quick-burning powder originally placed us at a disadvantage; so did muzzle loading. Hence it is that we need to bestir ourselves to equip our navy afresh. We are almost tempted to digress here, and point out that the small number of inferior guns carried in our ships of war further tells against us. Speaking generally, we carry much fewer guns of medium size than the French. Perhaps, we were right when our armor was able to defy the power of such guns; but directly it becomes possible for a medium gun to pierce our sides, everything is changed. So far, then, there is much in favor of vigorous action.

We have, however, considered only the length, proportions, and method of loading our guns. Where so much has recently been developed, has anything happened to bring up the question of actual construction? If so, seeing that we are likely to make a large number of guns for our service, surely special attention deserves to be given to this. Now, we all know that where great efforts are made to increase power we are sure to learn the measure of strength we possess, and especially has this held true in this country; because we have enlarged the chambers of our guns to a great extent as a substitute for deficiency in length. But chambering a gun is likely to bring a peculiar kind of strain on it. The surface at the bottom of the bore being increased, the gun's projectile will stand in a mechanical relation favorable to its discharge, but throwing increased longitudinal strain on the gun. This, with other causes, may have contributed to some of the results which have occurred. As a matter of fact, at all events, we have had more notorious instances of guns made in this

country bursting or yielding during the last two and a-half years than we have known since the first introduction of built-up ordnance. As we pointed out in a recent article, there is reason to fear that confidence in our guns is much shaken abroad, and that Krupp supplies guns where English ordnance used to go, even in vessels fitting out in the Thames. We especially wish to avoid raising the question of any particular accident. We only speak generally as to broad facts. We will suppose that it was perfectly right and natural that every gun should have yielded as it did; that we are convinced that the Thunderer gun was bound to protest against double loading; that the 100-ton gun showed how safely and gracefully a monstrous gun could pull asunder; and that the Angamos gun lies safe and sound, minus its trunnion ring, waiting to assert its innocence and strength whenever it may be fished up. Supposing all this, which has much to support it, the fact remains that steel guns have not had attention called to them in this way to the same extent latterly, and no one can pretend to say that our own service system stands as high as it did. Five years ago it was held that steel guns were liable to burst very dangerously, and those of wrought iron only to rend open under any strain. It would be difficult to maintain this in the presence of the fragments of the two Thunderer guns. Or if we go so far as to make special allowance for guns whose charges were exploded under compression and with exceptional violence, yet many will not do so. Rightly or wrongly, our wrought iron system of construction has had its reputation questioned abroad and at home. We do not mean that powerful guns cannot be made on it, for most of the very powerful guns existing are actually made on it. We do say, however, that immediate supplies of guns should be limited, and the whole question of construction should be fairly tried. If Elswick deserves consideration for the leading part it has taken in bringing out new type guns, may not the same plea be urged for Whitworth and Vavasseur for developing the manufacture of steel guns? If steel is good, the country will reap the benefit of the efforts made by private firms in the teeth of sweeping condemnation and discouragement. As we have pointed out, steel now claims the very qualities that caused us originally to give the preference to wrought iron. Personally we look upon steel as liable still to deceive. It has ways that need to be better understood yet, and we could quote examples of guns in support of what we say; but we may fairly question whether steel may not be proved to have powers so far in excess of those of wrought iron that a built-up gun may be made with sufficient margin to cover any danger arising from uncertainty, and yet able to bear more than our present service guns. Lastly, on the other hand, we have Sir W. Palliser's guns adopted on a sweeping scale on the other side of the Alantic—guns which have never been fairly burst, or anything like it, to our knowledge.

We have not the slightest wish to contrast our own system unfavorably with these. We only urge that its credit is so far questioned that we have no right to be satisfied without a trial. If we had either of the other systems in the service we should plead equally for this. Even from the point of view of our own Gun Factories and that of Elswick, we should urge a fair trial. Perhaps, of the two, Elswick is specially responsible for the confidence placed in our present system. We hear of an officer urging a plea somewhat in the following language: "You may set us down as prejudiced, but look at Elswick. Armstrong and Noble are not fools. Their credit and profits depend on the excellence of their guns, and they prefer the same system that we do." Clearly the question can only be settled by a thorough trial, and we trust that the country will be satisfied with nothing less. If our present system is the best, it will be well worth our while even pecuniarily to prove it so abroad. Our private factories really save us the necessity of having two or three Arsenals. It is important for their credit that they should be demonstrated to have guns capable of competing against the world. Let such a competition be invited. We are supposed to have a new committee deserving of extraordinary confidence. We have the highest authority for assigning to them independence tempered with discretion.

THE USE OF MILD STEEL FOR SHIPBUILDING.

By M. MARC BERRIER FONTAINE, Chief Constructor of the French Navy.

"Nautical Magazine."

After referring to the numerous papers which have been written on mild steel and its applications in England, the author described the parts played by France and England in the manufacture and development of mild steel, and its employment for shipbuilding amongst other work. He then went on to describe the chief elements of successful manipulation of mild steel, the principal of these being the necessary great skill on the part of workmen, who need to be encouraged in spite of the failures due to the want of experience in dealing with the new material. He next went on to consider the importance of having special tools for dealing with mild steel for shipbuilding, and especially of mechanical arrangements for taking the plates from ovens and quickly depositing them on the tables or dies upon which they have to be shaped, so that the work may be done without hurry and whilst the plate is still red hot. Much stress was laid on the use of gas ovens on the Gorman system instead of furnaces on Siemens' system for heating plates for hot bending, the Gorman oven being simpler in construction and management. At Toulon, as soon as a piece of metal is brought to a fitting temperature, it is seized in the oven by pincers, to which a rope is made fast, which, passing over other return pulleys, passes to one of two capstans. A workman starts this by pressing his foot on a lever close to the ground, a few turns of a Brotherhood engine being enough to get the piece thus drawn on to the plates alongside of the guides upon which it is to be moulded; one of its ends being quickly fitted against these guides, the other end is clutched by a claw which is hauled upon by a cord seized upon one of the capstans. Wooden mallets and swages are used for almost all the work, but when excessively sharp curvatures, &c., are needed, and hammers have to be used, the work is afterwards carefully annealed. Annealing is not otherwise resorted to, as the work is still at a color heat when finished.

The use of hydraulic presses gives the most satisfactory results when applied to the work of fitting and moulding angles or other work with sufficiently open curvature to admit of their being done cold. This is the case with all the deck beams, as well as for the greater part of the angles of the longitudinal stringers, and also for a very large proportion of the angles of the frames. At Toulon this work is performed by presses of graduated power from 5 tons to 100 tons, some vertical, some horizontal, to suit all possible cases. One press of a hundred tons is quite sufficient for straightening and moulding double Tee-bars of iron of $350\times150\times15$ mm., and of steel bars of $300\times148\times14$ mm. The profiles of these are among the most rigid forms of all those yet dealt with. A press of 50 tons is sufficient for straightening and moulding almost all the other forms used, from that of H or double Tee-bars of steel of $450\times130\times10$ mm. Finally, the small 10-ton presses can easily mould steel angles of $150\times150\times15$ mm., and 5-ton presses will mould steel angles of $120\times120\times12$ mm. The consideration of the effect of ragged holes and punched edges has led the authorities to forbid the use of the punch for making cuts in the plates, whether straight or curved, by a string of holes. In that respect the exceptionally large stretch of the Toulon hydraulic shears, which is 1.50 meter, or 5 feet, allows the shearing of the largest plates in any direction, and to cut sheets of any length up to 3 meters wide straight across. Curved cuts are obtained at once by means of a series of blades having graduated curvature, and brought sufficiently close to one another for them to cut out with sufficient exactness all shapes which can occur, whatever be their curvature. A collection of bent blades of this kind makes an outfit which is extremely valuable. The cutting edges of these blades

are spiral, as in Kennedy's spiral punch, thus having a shearing action. For splitting the ends of channel and other bars in the way often required for junctions with deck and flooring framings in ships, shears which are really long narrow punches working in long slot dies are employed. Cutting thus takes place on both edges, and the bars are not distorted. It may be said generally that the tools which carry out most exactly the work which has to be done, whatever it may be, are at the same time those which least upset the neighboring portions of the pieces of work upon which they act. Care is taken that the working angles of these different tools are set as may be most suitable for each kind of work. The most rigorous and the most unceasing attention is given by the fore men and by the workmen themselves to seeing that the cutting edges of their tools should always be kept in the most perfect condition. In order to secure this, grinding machines, with artificial emery grindstones specially arranged for setting the tools of various forms, are largely employed; these machines securing a regularity and a precision of edge which it would be impossible to obtain by hand. These emery grindstones are also used for taking off burrs, and finishing both plate work or moulded bars, as well as in finishing the small forged pieces, such as ring bolts, staples, hinges, and so forth, which form so large a part of modern construction. A saving of 22 per cent. has been found to be the result of long-continued trial of twist drills properly ground with emery wheel machines. The improvements in the results obtained by great care in every phase of the making of plates and moulded bars of steel, has led the Constructors of the French Navy to consider the desirability of relaxing, by slow degrees, the severe requirements which had at first been imposed by them for the execution of work of every description to which the plates and moulded bars of steel should be submitted in the dockyards. The cases in which it is judged necessary to anneal steel plates and moulded bars are now incomparably less frequent than they used to be a few years ago, and the number is still undergoing daily reduction. A return by degrees is being made to the use of the simple punch, without annealing, and without riming, for cutting holes in almost all the pieces of framework of the new constructions, reserving the use of the drill for those pieces only in which there is special reason for keeping up the greatest possible strength, having regard to the more important position that they have to take in the construction, or the exceptional strains they may have to bear. The vigorous precautions which the want of homogeneity at one time enforced are being discarded, and the most recent trials appear to prove that the loss of strength in punching and working is not much greater for steel than for iron. M. Fontaine therefore, with very cautious enthusiasm, remarks: "It seems to me, therefore, to be beyond doubt that at no distant period—as soon as the breakage of steel work becomes sufficiently rare not to require greater precautions in working these pieces than those which are applied to iron, that is to say—we shall very soon get into the way of punching nearly all the steel plates and moulded bars, and of only annealing them in exceptional cases, when they may have been submitted to very violent, and very trying deformations—a treatment, in fact, precisely similar to what we give to iron under the same circumstances." Owing to the more complete homogeneity and ductility of the steels, and also to the increased practice workmen have acquired with the new metal, the welding of steel plates and bars can now be effected as easily, as simply, and as satisfactorily as that of similar work in iron, without, M. Fontaine says, its being necessary to have recourse to any special process or to the use of any particular flux. "A great number of weldings of steel plates and angles have been broken as tests, and the results of these tests, in which the fracture often takes place outside the weld, have finally led us to consider the welding of thin plates of steel as being as certain and perfect as that of similar pieces of iron."

The author stated that the tensile strength demanded and the inferior limit imposed by the French authorities for steel plates and bars of various section were not the same for all thicknesses and sections, but were greater for the smaller and thinner sections. Excluding boiler iron, for which an exceptional

amount of ductility is considered indispensable, the inferior limit of tensile strength required by the French Navy is as a general rule higher than that specified by the English Admiralty, by Lloyd's Registry, and even by the Underwriters' Registry. It is only, in fact, for the thicker plates of from 20 to 30 millimeters, and for the stringers and butt straps of all thicknesses, worked across grain, that the French Navy allows a low limit of 44 kilogrammes per square millimeter, or of 28 tons to the square inch. This is specified for, all through by the Underwriters' Registry for all steel used in the hull. As the thickness of the plates diminishes the inferior limit required in the French Navy increases progressively, and for plates of from 6 to 20 millimeters in thickness, which includes nearly all those used in modern constructions, this limit already exceeds by 1 kilogramme per square millimeter that of the Liverpool Society. In order to be accepted for use in the French Navy, thin plates from 1 to 4 millimeters thick must be subjected to a minimum test of 30 tons to the square inch, or 47.25 kilogrammes per square millimeter, while the minimum tensile strength of the stringers and butt straps tried along the grain, and that of bars of all sections with the exception of double Tee-bars, Tee-bars and bulb iron, should be of a still higher tensile strength, namely, 48 kilogrammes in place of 47.25 kilogrammes per square millimeter. In the French Navy there is no superior limit to the tensile strength of steel presented for acceptance, so that the total effect of the conditions required by it has had the effect of furnishing it with steel plates and bars having an actual tensile strength very considerably in excess of those of the similar pieces of steel which are used in the same work in the building yards of Great Britain. This superior tensile strength is not bought in the French Navy at the cost of a reduction of ductility in the steel there employed, for a mimimum elongation of 20 per cent. is demanded.

As regards the calculations of tensile strength, it appears from the results of the numerous experiments that a mean figure of 48 kilogrammes per square millimeter, representing the ordinary breaking strain of steel plates and moulded bars such as are actually used in the French Navy, is adopted. The usual breaking strength of the iron plates and moulded bars of ordinary and common quality which are delivered to it, cannot, on the other hand, be regarded as greater than 36 kilogrammes per square millimeter at the outside. For iron a factor of safety of 6 is used. Using the same factor for steel it is reckoned that plates and moulded bars of this metal may be safely loaded with 8 kilogrammes per square millimeter. The limiting loads of 6 kilogrammes for iron and 8 kilogrammes for steel, are to one another as 1 : 1.33, consequently the inverse ratio of 1 to 0.75 indicates the reduction of thickness, and therefore of weight, which the substitution of steel for iron allows us to introduce into the plates and moulded bars which we use. This corresponds to an economy of 25 per cent. in weight. In order to take account of the loss of strength experienced during the work—a loss which may well be of greater relative importance in steel than in iron—and in order to take account of the existence of an inferior limit below which we cannot reduce the thickness of steel plates without risking their buckling, and although there does not exist any general formal rule about this, the Constructors of the French Navy, in agreement with the authorities of Lloyd's Registry, think that it is not safe to reckon on a final saving of more than 20 per cent. in the replacing of iron by steel in the weight either of the whole hull or of any part of it.

M. Fontaine then described at some length the experiments by the French Navy, which have shown that steel corrodes more rapidly than iron, and he concluded: "It would not be safe to affirm very positively, for instance, that this extremely rapid corrosion of steel plates is solely due, as Mr. Barnaby assumes, to intense galvanic action arising between the metal and the black oxide by which it is covered, and that consequently it will be sufficient to clear the plates of this black oxide by means of a weak acid bath in order to make their oxidation in sea water slow and uniform, like that which usually takes place on the surface of iron plates. It could not be affirmed with any certainty either that the greater or less rapidity with which

steel plates are attacked by rust depends solely on the greater or less proportion of manganese which they contain, as has been suggested by Dr. Siemens in 1878, in a paper read before the Institution, a suggestion, however, thrown out with some degree of doubt. Finally, it cannot be affirmed, as has been recently stated, before another society, that the corrosion of iron and steel plates is the more slow and regular in proportion as those plates contain a greater proportion of carbon or phosphorus, and that it is consequently not possible to find plates which possess the necessary ductility in combination with the valuable property of being attacked by rust only in a slow and regular manner when exposed to sea water." The French contractors consider that the cases in which steel rivets have hitherto been used do not seem to them sufficiently numerous, nor does the experience which results from them appear to them to have been sufficiently extended, nor sufficiently conclusive, to allow them to consider themselves in a position to dispense with the use of iron rivets.

The discussion on this paper was opened by Dr. Siemens, who repeated that mild steel corrodes no faster than iron, while others hold to the general sense of the above remarks of M. Fontaine. He also spoke of the rapid corrosion caused by the use of two metals such as steel plates and iron rivets. He also quoted some recent experiments by Professor Kennedy to show that mild steel was increased in strength by punching. Mr. White remarked that in punching strips it was well known that the material which was left at the sides was stronger as the hole was larger, as though the material was strengthened by the strain imposed, as iron or steel rods are by slight stretching. He also referred to the very complete machinery used by M. Fontaine for working steel cold, and to the numerous sections in which steel could be obtained in France, making hot work less frequently necessary. Mr. West said that pitting was often the result of the mechanical removal of paint covering, and that after a time corrosion gradually grew less and was no more than in iron. Harder steel, he observed, was gradually coming into use, and had increased in use since his paper on the subject.

THE BUILDING ARTS OF INDIA.

By GENERAL MACLAGAN, R.E.

From "The Building News."

EVERY one who has been in India has had opportunity, at some time or other, of taking notice of the buildings in the places at which he has had to take up his abode for a time. He may, indeed, be often in places where there is not much to be seen. The ordinary dwellings of the people will not in India, more than elsewhere, present much that will be thought worth observing. Yet, even in the simplest of dwellings, one may see how much can be made of very slender local resources, and how well, under the guidance of ancient custom and personal experience, they are turned to account. When you hear of cottage walls made of mud it does not sound nice to English ears. But, when you see it, you find it is something better than you thought. Put together solidly and thickly, it becomes one mass throughout, and, hardening as it dries, it forms a compact and effective protection against heat and against rain. In greater mass, this simple material forms the very efficient defensive works of what are well known as mud forts in India. How simply, also, do we find roof protection supplied by a skillful use of the common reeds and grass that grow in the jungle (jungle, let it be observed, is the familiar name both for forest and all uncultivated waste, which, except in driest tracts, commonly becomes a wilderness of shrubs and thorny trees and tall grasses). A roof covering of reeds, of no great thickness, does not truly afford much protection against the sun, and will not exclude the heaviest rain; but it is very wonderful to see what it can do. At places in the hills, you shall

see local material of another kind turned to account for roof covering, in a cheap and effective way; large flat slabs of easily-split stone, doing duty as slates, with lumps of rock laid upon them to hold them in their place. In India, as in most other countries, there is something worth noticing in the way in which the simplest of available means and materials are turned to account in very simple ways. In India we notice next something more. When we get above the very lowest and poorest kinds of human habitations, we begin to see manifested a demand for some ornament. The ornament may be of a very rude character, but there it is. Something is wanted more than that the building shall serve its direct and essential purpose. You may find ornamentation given in color or in wood carving. The whitewashed door-jambs may have streaks of ochre, diversified with curved lines and spots, and sometimes more ambitious efforts of the owner or the village artist. But there is something of a higher class in the rough carvings of the lintels and the door-posts of houses in even lowly, unpretending villages. Rough carvings, no doubt, they often are, of simple waving lines or geometric patterns, after the fashion of greater and more elaborate work in large cities. They are very unsymmetrical, perhaps, and very uneven. But this is nothing; the eye does not care to be critical in looking at these things. The ideas and aims are good, if the execution is something rustic. Rustic or not, the effect is very pleasing. It admits of variety of treatment, and the treatment rises to various degrees of excellence. But the great thing is that it is the expression of a felt desire for something more than mere needs. A something pleasing to the eye has become a need, and it finds, in its simple way, on the spot, the art that is capable of satisfying the demand.

There is often a sort of idea that one must go back a great way for specimens of excellence in various arts, and, among these, the arts connected with building. In India, as elsewhere, people have been in the habit of saying that no such buildings are erected now as in the days gone by, and that certain old arts are lost. It has been concluded that the capacity for such work has died out. It is one phase of the idea prevailing in all ages that former times were better. It may be the case that we cannot point to anything in India, built within the last hundred years, to equal the grand Hindu temples of Tanjore, the Jain buildings at Abú, the Taj Mahal at Agra, the Jama Masjid at Delhi. The occasion for erecting such buildings and the means are wanting. We are not warranted in adding, also, the ability to design and to execute them. It is almost needless to say that for great and beautiful buildings, great expenditure of money and labor is required. It was perhaps a stern necessity that stopped the second tower alongside the stately Kutb Minár at Delhi, and the second tomb opposite the Taj, and elsewhere left intended works unfinished. The ability was not wanting, but the means.

We are not fully able to say where the earliest building arts came from, of which we see the illustrations in India. There is nothing to show that any distinctive art of this kind was brought in by the intellectual race which, at a remote age, entered India from the northwest, and gradually extended southwards over their new country. There is reason to believe that they found architecture among the people of the south. In whatever way acquired, the Hindus have shown a very admirable power of forming a style, and working it with great variety of treatment, and great beauty of detail, though not always equal soundness of construction. No special reference is made by the historians of the Greek invasion to fine buildings in India at that time. But the mention of Taxila as a great and magnificent city, seems to tell of buildings at that place which were of some importance. And now we have there only the ruins or traces of numerous small Buddhist topes; and a few other remains, which are undoubtedly Greek.

Mohammedan architecture, which came in from the West, assumed more graceful forms in India than it had done in Persia. It developed other forms again when it traveled westward, and took root in Spain. Moreover, in India it adopted, in the time of the Emperor Akbar, and under the influence to some extent of his enlarged and liberal views, Hindu forms of ornament, as well as of construction, in works distinctly Mohammedan, and this in a manner very effective and beautiful.

And, similarly, in many parts of India, we find Hindu buildings of recent centuries adopting, with more or less success, Mohammedan forms of constructions, with corresponding ornament. They would appear to have something in common, in their fundamental ideas, which allows of these adaptations without marked fault. It is otherwise when we see Oriental forms trying to adopt Italian features, as at Lucknow, where, in some cases, the mistake is aggravated by the effort to make a good show with inferior means.

The dome and arch, borrowed by some modern Hindu buildings, are foreign to pure Hindu work. The construction was unknown to the earlier Indian builders. A well-known illustration of this is to be seen in the great gateway of the Kutb inclosure at Delhi, built in the earliest Pathan times. The arch-shaped entrance is not an arch, but the form is given by horizontal courses of stones projecting one beyond another, till they meet. It would appear that Hindu workmen, unacquainted with the arch construction, were employed to execute the work to a prescribed arch form. The same thing is to be seen in a covered passage at the ruins of Ránigatt, a Buddhist fortified monastery, a little beyond our Yusufzai frontier, to the west of Torbéla on the Indus, above Attok. Likewise in some old bridges in Orissa. The high pyramidal roofs of Hindu temples in the south of India have a dome-shaped crown, which is not a dome. It is scarcely necessary to say that the large Buddhist *topes*, the large buildings of the beehive shape, now pretty familiar from drawings and photographs, are not domes, but are formed on a solid core.

One of the most observable things in connection with the best of the old Hindu building and groups of buildings, is the attention that has been paid to choice of site, and the admirable skill with which the choice has been made. We admire the way in which English abbeys and monasteries found out lovely sheltered shops in which to plant themselves, in green and peaceful valleys of our own land. No less happy has been the success of the Hindus in the choice of situations for their buildings. Temples, in shady glens and on wooded hill-sides, have been placed where they have beautiful back-grounds of crag and forest, of rich color and of varied foliage. Such are numerous Hindu buildings, small and large, in Central India and Southern India, in Rajputana, in Kashmir, and elsewhere.

It is noticeable that Buddhist buildings, monasteries, temples and topes, or relic monuments, are many of them built on the open plain, even in the neighborhood of better ground, with no reason that is now apparent for the choice of their position. Other buildings of the Buddhists occupy, like those of the Hindus and the Mohammedans, commanding sites which seem to have been carefully selected. Some, at least, of those which stand on what we might be disposed to think chance sites, are connected with incidents in the traditional life of Buddha, which may account for the exact position in which they are built. And others probably have a similar history.

Our building predecessors in India did not meddle much with the large rivers. They had to build some defensive walls and terraces on their banks. Bridges, of course, they did not build across such rivers. Never till railways brought their demand for a continuous running line did the British Government attempt anything more than floating-bridges on these rivers in the plains. And when we consider the character of the rivers and the requirements of a permanent bridge, we have no reason to be surprised that even the wealthy Moghul princes and their engineers did not apply their strength and skill to works of this class, and were content, as their predecessors for many centuries had been, to use boats. The pier foundations of one of our railroad bridges were scooped away by the stream, at a depth of 70 feet below the river-bed. Another of these rivers, at a place where a railway-crossing is being built at this present time, has been known to rise, in exceptional floods, upwards of 90 feet above its low-water level. We can feel, in the face of facts like these, that it was right to let the permanent bridges wait till the days of railroads.

Over swift and rocky rivers in the hill country, which it was necessary to cross by a single span, suspension bridges of hempen ropes or cables made of birch-twigs have long been in use. On roads

where laden cattle were used, something different was required for crossing the rivers. The kind of bridge called *sanga* in the northern hills is a good and useful construction, for which the materials were commonly available. A number of beams, laid side by side, project from each bank of the river, slightly pointing upwards, firmly secured by being built into the bank, and heavily laden at the shore end. Another set of beams is made, in like manner, to project beyond these, and others again till the space left in mid-stream can be crossed by single timbers. It is, in fact, like the overlapping stone construction. On cart roads, where something more is wanted, there are no masonry bridges in large single spans by native builders, such as have now been built in British times. It may be of interest to mention that a few years ago, two brick bridges, each of a single arch, 140ft. span, were built (by Lieut.-Colonel James Browne, R.E.) over two of the rivers of the Kangra district in the Punjab, on the main line of cart-road along that beautiful valley.

In the choice of their materials, we see much to admire in the works of the native builders who have gone before us in India. In the most lively times of Moghul building energy, the free outlay on grand works brought costly stone from long distances, and well has their white marble and red sandstone been turned to account. The most ordinary building materials, being such as the earth supplies, have been the same in all ages. The difference in their use, at different times and places, consists in the choice that is made of the better or the worse, and in the means available, in money or appliances, for conveying what was selected to the place where it was to be used.

When we speak of power to convey what was selected to the place where it was to be used, we observe that in India this power is not often illustrated, as in some other countries, by great buildings constructed of enormous stones. This does not seem to have been one of the favorite ambitions of the builders whose work is now to be found in India. There are, of course, big stones in some buildings, but their bigness is on a different scale from that adopted in other lands, and is not such as to give rise to the admiration which we feel in seeing what has been done elsewhere. There is a big trough at Vizianagar, in Southern India, cut out of a single stone between 30 and 40 feet in length, but it is probable that it has never been moved from the place where it was made. There is a temple in Kashmir which is built of five stones, one for each of the four corner piers, with its portion of roof, and the fifth a square-pointed piece, which crowns it. But the whole building is not a quarter of the size of one of the big stones in the terrace wall of the temple at Baalbek.

The masonry of the outer inclosure walls and basements of certain Buddhist works in Northwestern India, perhaps the oldest masonry now standing in that part of the country, is of a peculiar kind of effective roughness. It is without mortar. The large stones are unsquared. They have a tolerably flat face, but there has been no endeavor to make them fit each other. Between the stones are irregular gaps of varying width, which are filled in with pieces of slaty rock, all laid flat, and firmly driven home into these wide joints. There are many specimens of this kind of work in the Buddhist tract of the Punjab frontier districts.

There are likewise in India stone circles of upright blocks, like those well known in England and other countries. In one of these circles near the village of Asota, Yusufzai, northeast of Peshawar, about 50ft. in diameter, the stones have been roughly hewn on two sides. Their greatest thickness is about 2ft., and the greatest height of any now standing is between 11ft. and 12ft.

It is remarkable how little (speaking generally) even the oldest buildings in India have suffered from exposure; and this exposure sometimes is of a very trying kind. The buildings bear testimony to the good choice that has been made of the stones used in them. A dark and hard blue limestone has been a favorite material with the Hindus. It receives fine sculpture, and retains sharp, well-defined edges. Much of the Buddhist sculptured work in the northwest of India, where sculpture is very abundant, is on hard clay-slate. The sculpture on these buildings is mostly on the interior faces. The Jain temples at Dilwara, on Mount Abú, profusely and beautifully carved inside, are of white marble. Out-

side, these buildings are of studied plainness, not as the Hindu buildings, great and small, in all parts of India, which carry much ornamentation outside; the largest of these—the magnificent temples of Tanjore, Trichinopoli, Tinnevelly, Madura, and other places in the south, of Nassik in the west, and of Orissa in the east — being covered throughout with elaborate carved ornament and sculpture. On the hills of the Salt Range in the Punjab (hills containing the great mines of rock-salt) are Hindu temples of a gray limestone, naturally of a somewhat honeycombed texture, which has suffered further from the weather.

In the great imperial cities of the Moghuls white marble and red sandstone have been largely used together, and with excellent effect. The marble is polished, and well withstands the weather. But though it suffers little from the weather, there is another kind of injury, very subtle and troublesome, to which it is exposed. However carefully and closely the stones have been laid, yet, into the joints between them, on domes and terrace roofs, on cornices and parapets, the seeds of shrubs and trees will find their way, and there begin to grow and thrust their roots beneath. The pipal tree is particularly insidious in this kind of attack on unwatched stone-work, and if allowed to stay, as we see it has been sometimes, it will slowly, but strongly, dislodge the stones, and, if there is water near the foot of the building, will push its long roots through the wall, and down towards the moisture that it seeks.

In the Mohammedan buildings of Akbar's and later reigns—the seventeenth century and the latter half of the sixteenth—the red sandstone is very largely used. There are buildings of earlier date, now six and seven centuries old, in which this stone, frequently bearing Arabic inscriptions in raised letters, is still sharp-edged and fresh. It contrasts very favorably in this respect with many buildings in England sadly defaced by weathering of the sandstone. Oxford, perhaps, looks more venerable where the edges of the stone are worn and rounded, and the form of the moulding lost; but it would have been better if this had not happened. There are buildings in this country of a sandstone much resembling in color and general appearance that of the Moghul works in Northern India, but very different in durability. The exposed masonry of the Church of St. Michael, at Coventry, is seriously worn away, and seems to be crumbling continuously now. In past days, endeavor had been made to hold together with iron straps parts that were in danger of separating, and in some of these places little more than the iron strap now remains.

In the Indian buildings in which both white marble and red sandstone are used, the contrast of color is sometimes given by the use of the different materials for different parts of the building, sometimes by using them together, in alternate bands, or otherwise combined. Color is likewise shown in the Mohammedan buildings by inlaid work in the piers of the arcades, the spandrels of the arches, and other parts, and by lines of black marble inlaid in the white. The inlaid work is executed on a large scale in some buildings. The stones chiefly used are bloodstone, carnelian and agates. The inlaid work, besides that on the borders of panels and elsewhere in geometric figures, is chiefly representations of flowers in conventional style, and often with much freedom from the rigid symmetry which prevails in most Oriental designs. Inscriptions in the Persian or Arabic characters are either inlaid or carved in raised letters, not engraved like our inscriptions. In the interior of the great reception-halls of imperial buildings, and the more ornate private apartments, gilding also was much used. But some of the most beautiful of these Mohammedan buildings are those in which there is least color or applied decoration of any kind, so elegant are the forms and so just the proportions of the several parts, so refined the mouldings, and so true the execution. One other kind of ornamental work of much beauty is especially to be observed in these buildings, the stone screen-work of open tracery—large thin slabs of marble or sandstone, pierced with geometric figures of great variety. Very good specimens of this kind of work are to be seen in the Indian section of the South Kensington Museum.

The comparatively small variety of color thinly applied on the outside of the Táj Mahal at Agra—the Indian building perhaps best known in England—is the cause of its having frequently been felt,

at first sight, to be heavy. It is not really unrelieved by variety. Besides some inlaid colored work, it has straight lines of black marble inlaid, black zigzag lines on the thin engaged pillars at the corners, inlaid ornament following the outline of the parapets, and encircling the neck of the dome, and inlaid inscriptions in large letters. But so immense is the mass of white marble, that the relief thus afforded is comparatively small. A little study of the building reconciles the spectator to this massiveness, and only leaves him full of wonder and delight with the beauty as well as grandeur of the building. Its surroundings are on a scale of corresponding magnificence. The great square inclosure, with its splendid gateway, and the minarets at the corners; the straight-lined garden and its broad masonry channels, with shallow stream of water and rows of fountains in the middle; the sombre lines of tall dark cypresses, with trees of more varied foliage and color throughout the garden;—it is with these things about it, and a sense of great stillness and solemnity over the whole, that we look at this magnificent marble tomb. And we feel how large a measure of respect and gratitude is due to the men who did all this, to those who purposed and devised a monument on this scale of grandeur, and those who executed it in a manner worthy of the conception. Have not we reason to be glad that the wealth of building-power in those days threw itself into forts and palaces, mosques and tombs, pleasure-gardens for princes, and serais for travelers? What should we not have lost if Shah Jahán, for instance, had been a prince of smaller and more modest aims, and had bestowed the best efforts of his architects on jails and court-houses, town-halls and barracks, hospitals and schools? Their time has come. But it is better for art that Shah Jahán had his turn at something else. The world has gained.

If defect of color enhances the noble massiveness of the *Táj*, we feel this to be in agreement with the nature and purpose of the building. The use of color on Moghul buildings was well understood and very general. In the beautiful and wonderful city at the head of the Adriatic, which so many travelers to and from India have now-a-days an opportunity of seeing, we find a large amount of coloring of buildings, most of it very Oriental in character. But India has nothing to show of exactly the same kind. Buildings of brick, in India, if not faced with stone, were thickly plastered, and the coloring was given by figured designs, not whole surfaces of color, or by a facing of glazed work, which is of two kinds, on pottery and on plaster.

The use of glazed tiles and glazed plaster seems in India to be most frequent in the western frontier provinces of Sinde and the Punjab. But there are many good specimens at Gwalior, Delhi, and elsewhere, of buildings thus colored. The work goes by the general name of *Kashi*. Glazed tiles are used when a large surface is to be uniformly colored. Patterns also of different colors are given on single tiles. The glazing on plaster is used for colored devices, made up of separate small pieces, of the different colors, and these are laid on and cemented on the surface of the building. The plaster, which is made of lime and sand, receives first a very thin coating of glass containing lead, which both gives a fair smooth surface for the colored glazing that is to be afterwards applied, and enables it to adhere. Both these arts seem to have been imported from Persia. The earliest specimens of glazed-tile work known are at Mashad and Tabriz. The name Green Dome (*Sabz Gumbaz*) which is given to a conspicuous building at Mashad, of which the city is proud, is also borne by a tomb at Lahore, of which the green covering of the dome is in good preservation. Another at Lahore is similarly called Blue Dome (*Lila Gumbaz*). The cities of Moultan in the Punjab, and Tatta, and Hyderabad in Sinde, and others, have good specimens of this kind of work, as well as of the plaster *Kashi* work used for wall decorations and inscriptions. Lahore has many of great excellence and beauty; the most complete is the mosque of Wazir Khan, in the heart of the city. The figured tile work is now carried on in Sinde, at Tatta, on the Indus, and at Hala, 30 miles north of Hyderabad. The Masjid, built by Shah Jahán, at Tatta, has had the deficient tile work lately restored. At this place there is no glazed work of the other kind—that is, on inlaid pieces of plaster.

Indian brickwork, except in wells, is rarely seen, for it is always covered, or meant to be covered in one of these ways. Its quality is excellent, though its appearance is coarse, as it was not meant to be seen. Well-burnt bricks are united by well-made but rough mortar, the mortar courses being of great thickness, often much thicker than the bricks, giving the work the appearance almost of a concrete wall with thin bands of red brick. It is indeed a concrete. A similar material is used for terraced floors and roofs. And there are cases where—the wood and tiles on which it was laid having decayed and fallen away—the terrace covering has remained, spanning the gap, as a single block of artificial stone or concrete bridge.

In stone buildings in various parts of the hill countries of India, the insertion of horizontal beams at intervals in the masonry, which is a common constructive arrangement, gives a pleasing variety to the outer face of the work, like the use of stone of different colors. The practice is similar to the use of bonding courses of red brickwork, which we see in Roman walls of stone masonry in Britain. This was well shown in the old wall lately discovered in extending the railway buildings in the neighborhood of Fenchurch-street Station. The bright red bands were of tiles or bricks of large size, of which there were three courses in each horizontal band. Similar bonding brickwork of bright color is to be seen in a massive Roman wall at Leicester; of which English builders have taken advantage in a very practical way, by using part of the materials, both brick and stone, for the adjoining church of St. Nicholas. In the church the construction is repeated, stone masonry with courses of brick at intervals. The cathedral of Carlisle has in like manner helped itself to stone from a neighboring Roman wall.

In these cases, as in many others, perhaps no great harm was done, as the walls were plain and uniform masses of solid masonry, interesting chiefly on account of their history and their construction, and having plenty of the work still left to satisfy this interest. But the practice is a dangerous one. It has been often followed, in all countries, and has sometimes not been quite so harmless. We cannot tell now what we have lost at old Delhi. Bernier says, Shah Jahán's new city, which was being built when he was there, was conveniently near the old one, which supplied quantities of building material ready for use. Very likely the honest intention in the first place was to take only the stones from absolute ruins. But we know how difficult it is to get any rule of this kind rigidly adhered to, and to prevent the despoiling of buildings which, if in a sense ruins, are yet ruins to be carefully and tenderly preserved.

OBSERVATIONS ON THE MOVEMENT OF WATER IN STREAMS.

By P. GRAEVE.

Translated from Civilingenieur for Abstracts of Institution of Civil Engineers.

THE law of the movement of water in streams is still imperfectly known, partly in consequence of the complicated character of the motion, and partly because observations have been made with imperfect instruments.

Some observations by the author on the Oder and Warthe are first given. A Woltmann's current meter was used, the curve of revolutions of which had been already very carefully determined. Velocity observations were taken at 5 meter (16.4 feet) distances horizontally, and at 0.2 meter (8 inches) distances vertically, from 0.1 (4 inches) below the surface to 0.25 meter (9.8 inches) from the bottom. Altogether two thousand five hundred observations were made. The results were as follows:

	Discharge. Cubic meters. (35.316 cubic ft.)	Mean Velocity. Met. per sec'd. (3.28 ft.)
Oder, above mouth of the Warthe.....	155.4	0.73
Warthe	185.7	0.917
Oder, below junction of Warthe.....	336.0	0.712

The curves of velocity in each vertical are given for the three river sections at which the observations were made. These curves are so irregular that very little can be inferred from them immediately as to the law of diminution of velocity with increase of depth. In all the velocity diminishes more rapidly in the lower than in the upper part. The sudden diminution very near the bottom may perhaps be due to the silt in the water. Mean curves were then constructed by combining observations at corresponding heights. The mean curves were found to be much more regular than the single curves, so that the large irregularities of the latter neutralize each other. The curves confirmed the conclusion of Hagen, that in broad streams the greatest velocity is at the surface, unless accidental causes reduce the surface velocity. The curves agreed nearly with a parabola having a horizontal axis at the water surface, and not so well with a parabola having a vertical axis and the vertex at the river bed. The mean velocity deduced from the parabolic curves is a little less than that of the corresponding mean curves. For the parabola with horizontal axis at the water surface, the mean velocity is found at 0.5773 of the depth; and for the parabola with vertical axis, at 0.5555 of the depth. Taking the velocities from the four mean curves at these depths and comparing them with the actual mean velocities, it is found that the agreement is closer at 0.5773 of the depth than at 0.5555; but in neither case is the difference from the mean very sensible. The ratio of the surface and mean, and surface and bottom velocity, is then examined. These ratios vary, not only for different inclinations and different water depths, but also for the same inclination and different depths of stream. Hence the mean velocity can be inferred from the surface velocity observed by floats only with approximate safety. Horizontal curves of surface and mean velocity are then examined. These do not confirm the conclusion of some haudraulicians, that the curves of horizontal velocity are parabolas. Nor does the form of the curves agree well with that of the bed.

The observed mean velocity of the Oder and Warthe is then compared with the velocity calculated by various formulæ. The following summary shows the results:

	Warthe.	Oder, below Junction of Warthe.
	Meter per second.	Meter per second.
Observed mean velocity.	0.917	0.7113
Humphreys' and Abbot's formula	0.98307	0.9452
Grebenau's formula	0.975	0.962
Bazin's formula	0.847	0.763
Gaukler's formula	1.3061	1.0515
Bornemann's formula	0.0037	0.00055
Hagen's formula (old)	0.904	0.89
" " (new)	0.941	0.916
Ganguillet and Kutter's formula	0.727	0.629

It may be concluded that the most complicated formulæ, such as those of Humphreys and Ganguillet, are not in all cases more trustworthy than the simplest, such as Hagen's and Bazin's. It is doubtful if any formula is applicable in all cases; and it appears that Hagen has taken the right path in adopting two different expressions for small streams and more important rivers.

A HEAVY gun, believed to be one of the oldest pieces of ordnance in existence, has been sent home by the Governor of Cyprus, for the Museum of Artillery at Woolwich. It is of cast iron, and weighs 25 cwt. The manufacture is probably Venetian, and the ancient weapon is well shaped, in the form of a cup or goblet, the mouth being wide and deep, to hold a large stone shot, while the narrower pedestal is hollowed to receive the powder charge. A round stone, weighing about 6 cwt., has been sent with the gun, and it is suggested that this is the kind of missile fired from it, as proved to have been the case with similar guns in England. One which it somewhat resembles is already in the Rotunda at Woolwich, having been found in the moat at Bodiham Abbey, and specimens of the stone cannon balls are already in that museum. The gun from Cyprus is in much better preservation. The cup or mortar is 19in. deep and 18in. across, and the external diameter is 26in., which allows 4in. for thickness of metal. The powder chamber, 7in. across, extends some 30in in a tunnel, behind the mortar, and terminates in a vent or touchhole going off at right angles, and fully an inch in diameter.

THE STRONGEST OF THE BRONZES.

A NEWLY DISCOVERED ALLOY OF MAXIMUM STRENGTH.

By ROBERT H. THURSTON.

Transactions of American Society of Civil Engineers.

THE writer, when conducting a series of investigations of the properties of the copper-tin-zinc alloys, in the Mechanical Laboratory of the Stevens Institute of Technology, by request of a committee of the U. S. Board, organized under an act of Congress secured by a request of the American Society of Civil Engineers, and of gentlemen taking an interest in that enterprise, was led to devise a method of planning that research* and a system of recording data that has since led to the discovery of alloys of probably the maximum possible strength obtainable by any combination of the elements studied.

This system is briefly the following:

In any triangle, B, C, D, Fig. 1, let

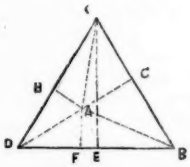


Fig. 1.

fall perpendiculars from the vertices to the opposite sides, as for example, $\overline{CE}$. From any point within the triangle, A, let fall perpendiculars $\overline{AG}$, $\overline{AH}$, $\overline{AF}$, and draw $\overline{AB}$, $\overline{AC}$, $\overline{AD}$ to the vertices, thus obtaining three triangles, $\overline{ABD}$, $\overline{ABC}$, $\overline{ACD}$; their sum is equal to the area of the whole figure $\overline{BCD}$.

Now we have, since the triangle is isoceles, and

$$\frac{\overline{CE}\times\overline{BD}}{2}=\frac{\overline{AF}\times\overline{BD}}{2}+\frac{\overline{AG}\times\overline{BC}}{2}+\frac{\overline{AH}\times\overline{CD}}{2},$$

$$\overline{CE}\times\overline{BD}=(\overline{AF}+\overline{AG}+\overline{AH})\times BD;$$

and

$$\overline{CE}=\overline{AF}+\overline{AG}+\overline{AH}$$

which follows wherever the point A may be situated; it is true for every point in the whole area $\overline{BCD}$. Assuming the vertical $\overline{CE}$ to be divided into 100 parts; then

$$\overline{AF}+\overline{AH}+\overline{AG}=100 \text{ and } \frac{\overline{AF}, \overline{AH}, \overline{AG},}{100\ 100\ 100}$$

measures the relation of each of the altitudes of the small triangles to that of the large one.

But we may now conceive the large triangle to represent a triple alloy, of which the areas of the small triangles shall each measure the proportion in which one of the constituents enters the compound, and

$$\overline{BCD}=100 \text{ per cent.}=\left(\frac{\overline{AF}}{100}+\frac{\overline{AG}}{100}+\frac{\overline{AH}}{100}\right)$$

$\overline{BD}$, or $\overline{CE}=100$ per cent. $=\overline{AF}+\overline{AG}+\overline{AH}$ per cent. and the altitude of each small triangle measures the percentage of some one of the three elements which enter that alloy which is identified by the point. Thus every possible alloy is represented by some one point in the triangle $\overline{BCD}$, and every point represents and identifies a single alloy, and only that. The vertices B, C, D, in the case to be here considered, represent respectively, copper=100, tin=100, zinc=100. Thus, having determined a method of studying all possible combinations, the writer next prepared to examine this field of work in the most efficient and complete manner possible, with a view to determining, by the study of a limited number of all possible copper-tin-zinc alloys, the properties of all the numberless, the infinite, combinations that might be made, and with the hope of detecting some law of variation of their valuable qualities with variation of composition, and thus ascertaining which were the most valuable for practical purposes.

With this object in view, the triangle laid down to represent this research, was laid off into concentric triangles, Fig. 2,

*On a new method of planning researches, &c., by R. H. Thurston, Proc. Assoc. for Advancement of Science. Vol. XXVI.

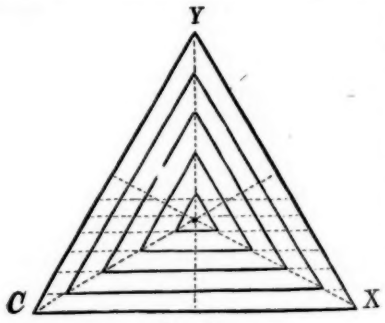


Fig. 2.

varying in altitude by an equal amount—10 per cent.—on which were laid out the following series of alloys:

COPPER-TIN-ZINC ALLOYS.—THURSTON.

Copper.	Zinc.	Tin.	Copper.	Zinc.	Tin.
10	10	80	30	40	30
10	20	70	30	50	20
10	30	60	30	60	10
10	40	50	40	10	50
10	50	40	40	20	40
10	60	30	40	30	30
10	70	20	40	40	20
10	80	10	40	50	10
20	10	70	50	10	40
20	20	60	50	20	30
20	30	50	50	30	20
20	40	40	50	40	10
20	50	30	60	10	30
20	60	20	60	20	20
20	70	10	60	30	10
30	10	60	70	10	20
30	20	50	70	20	10
30	30	40	80	10	10

These alloys were first all tested in the Autographic Recording Machine, and their strain diagrams were carefully studied. It was at once found that only a very few were of great value, and that the alloys represented by that part of the field lying on the tin-zinc side of a line running from copper = 70, tin = 30, zinc = 0, to the point copper=40, zinc= 60, tin=0, were too soft or too brittle and weak to be of value. The research was now restricted to the examination of alloys lying nearer the point copper = 100, *i. e.*, the upper vertex of the triangle as seen in the figure, and all such alloys were tested by tension, compression and torsion, and by transverse stress.

The results were quite accordant, and the quality of the metal could be judged as well by one set of data as by another, although, as a matter of course, the strain diagram, obtained automatically, gave the best idea of the nature of the metal where the observer had been accustomed to that method. When the figures thus obtained had been entered on the triangular map, lines of equal strength, of equal ductility, or of equal resistance could be drawn, as in topographical work lines of equal altitude are drawn, and the map became thus a useful representation of the valuable qualities of all possible alloys.

Figure 3 represents such a map* of all copper-tin-zinc alloys. The scale of altitudes is obtained by considering the relation of tension to torsion resistance as 25,000 pounds per square inch (1,758 kilograms per square centimeter) for each 100 foot-pounds. (13.82 kilogrammeters) of torsional moment for the standard test specimen, which specimen was turned to a standard gauge, and made $\frac{3}{4}$ inch (1.84 cm.) diameter and 1 inch (2.54 cm.) long in the cylindrical part exposed to strain.

These facts, as determined experimentally, were subsequently still better exhibited by another method devised by the writer for class illustration; thus:

Upon a triangular metal base, laid off as above, erect a light metallic staff by drilling a hole for its support at each point laid down as representative of an alloy tested; make the altitude of each of these wires proportional to the strength of that alloy. There is thus produced a forest of wires, the tops of which are at elevations above the base plane proportional to the strengths of the alloys studied. Similar constructions may be made to represent the elasticity, the ductility, or any other property of all these alloys.

Next fill in between these verticals with clay or, better, with plaster, and carefully mould it until the tops of all the wires are just visible, shining points in the now smooth surface of the model. The surface thus formed will have a topography characteristic of the alloys examined, and its undulations will represent the characteristic variations of

* Reports U. S. Board testing Iron, Steel, &c. Washington. 1878—1881.

quality with changing proportions of the three constituents.

This was made for the writer, and was cast in an alloy which is the subject of this paper, the plaster cast made as above being used as a pattern, and this cast is used in lecture-room illustration, and is

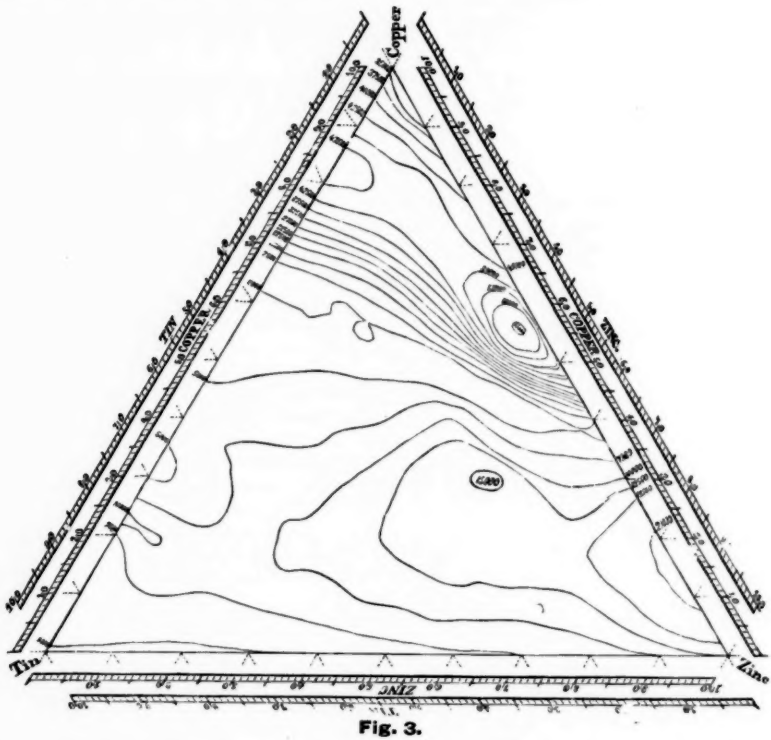


Fig. 3.

supplied where demanded to other institutions.

Figure 4 is a good representation made from a photograph of the model for the American Association for the Advancement of Science.*

The remarkable variations of quality here so strikingly shown, naturally attracted the attention of the writer, as of every one to whom he exhibited these models and maps, and a further investigation was made.

The alloys studied were orignally intended to furnish data during a preliminary research that should serve as a guide

* Proceedings, 1878, Vol. XXVI.

in a later and more complete study of this important and intensely interesting field of investigation; the plan was never completely carried out, in consequence of the failure of Congress to make needed appropriations and the consequent demise of the Board.* These alloys were purposely made precisely as the brass founder is accustomed to make them, without other precautions than those observed by every good founder, and without using any of the deoxidizing fluxes—as phosphorus—that would have been experimented with later. The intention was to make this first survey of the field rapidly, inexpensively, and in such a manner as to give a good idea of the best way to pursue the later and much more exact research, while giving the founder a good idea of the nature of

* An effort which has been recently made to re-establish the Board has not yet (December, 1880,) met with success.

the metals that he turns out in every day work.

The data obtained were consequently exceedingly variable, and the results of this work indicated as one, and not the least valuable, of deductions from it that the same alloy, and especially where the proportion of copper is great, may give very different figures when tested according as it is more or less affected by the many circumstances that influence the value of all brass-foundry products.

line marked 65,000 pounds per square inch (4,570 kilogs. per sq. cm.) tenacity, and is represented on the model, Figure 4, by the peak of the mountain seen at the farthest side—the copper-zinc side as drawn.

This is obviously the strongest of all bronzes, and an alloy of this composition, if exactly proportioned, well melted, perfectly fluxed, and so poured as to produce sound and pure metallic alloy, with such prompt cooling as shall prevent

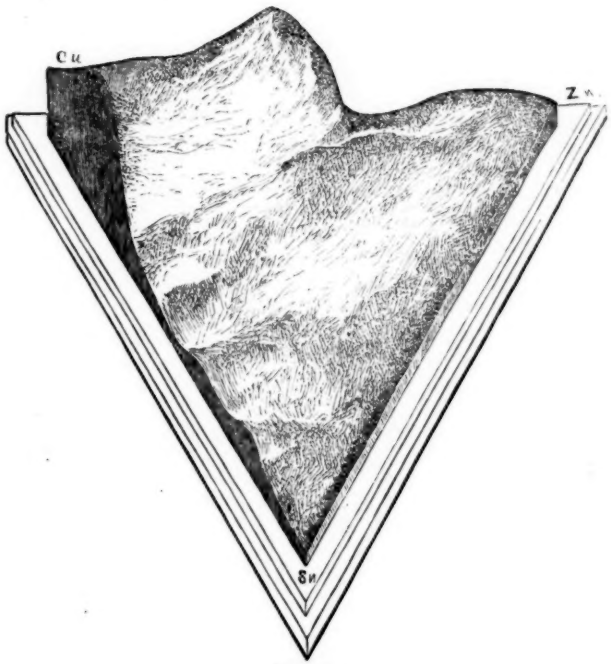


Fig. 4.

Some of the variations in the model are probably due to such accidental circumstances, and quality shown by any individual alloy is representative of a mean which the writer was often compelled to deduce from observations which were quite discrepant. But allowing for all such minor variations, it is evident at a glance that the alloys of maximum strength are grouped, as shown in Figures 3 and 4, about a point not far from copper=55, zinc=43, tin=2. This point is encircled in the map, Figure 3, by the

liquation, is the strongest bronze that man can make.

The writer finally made this alloy, and of it constructed the model represented in the last figure. It is a close-grained alloy of rich color, fine surface, and takes a good polish. It oxidizes with difficulty, and the surface then takes on a pleasant shade of statuary bronze green. Testing it, it was found to have considerable hardness, but moderate ductility, though tough and ductile enough for most purposes; it would

forge if handled skillfully and carefully and not too long or too highly heated, had immense strength, and seemed unusually well adapted for general use as a working quality of bronze. In composition, however, it is seen to be a brass, with a small dose of tin.

The alloy made as representing the best alloy for purposes demanding toughness as well as strength contains less tin than the above composition. Cu., 55; Sn., 0.5; Zn., 44.5.

It had a tenacity of 68,900 pounds per square inch (4,841 kilogs. per sq. cm.) of original section, and 92,136 pounds (6,477 kilogs.) on fractured area, and elongated 47 to 51 per cent., with a reduction to from 0.69 to 0.73 of its original diameter.

No exaltation of the normal elastic limit was observable during tests made for the purpose of measuring it if noted. This alloy was wonderfully homogeneous, two tests by tension giving exactly the same figure 68,900. The fractured surface was in color pinkish yellow, and was dotted with minute crystals of alloy produced by cooling too slowly. The shavings produced by the turning tool were curled closely, like those of good iron, and were tough and strong.

The strain diagrams from the autographic machine are shown in *fac simile* and two-thirds of full size in the accompanying Plate 1. Their tenacity, as estimated from their resistance to torsion, is nearly equal to that determined by direct experiment, and the four samples tested 1,001 A, B, C, D, have given strain diagrams that are all nearly precisely alike. They exhibit an elastic limit, *e*, at about two-fifths their ultimate resistance, and just about the same as a piece of excellent gun bronze (Cu. 90; Sn. 10 per cent.), 1,252 A, the strain diagram of which lies beside them in dotted line. Their elastic resistance, which is measured by the area of the curve up to *e*, is superior to that of the gun bronze, and their elastic range is seen to be greater on inspection of the "elasticity lines," *é é*. In ductility they excel 1,252 A, but not greatly, as is seen by comparing 1,001 A with 1,252 A. Their toughness is shown by the great area and the altitude of the curve; their excellence of quality is also shown by its smoothness of outline. The homogeneousness of structure is exhibited by the similarity of the diagrams and by the smoothness of the bend at *e*, which marks the elastic limit.

At *f* is a depression of the normal line of elastic limits produced by 17 hours intermission of distortion under the load there carried. This slight depression marks this alloy as one of the "tin class."

Diagram 1252 B is given by a very fine gun bronze; 1001 *x* is an hypothetical diagram, such as would be produced were the alloy here described so carefully fluxed and cast as to exceed in strength the unfluxed alloys actually tested, 1001 A, B, C, D in as great a proportion as 1252 B excels 1252 A. The diagram 1001 *y* would be produced were it possible to so far improve this alloy as to cause it to excel 1252 A as greatly as No. 1001 actually did excel the gun bronze made under similar conditions in this preliminary rough work. No. 1004 A is copied to exhibit the immense superiority of the alloy 1001 to one but little removed from it and which is considered by some brass founders an excellent composition.

It is impossible to say, without direct test, to what extent the alloys shown in figures 3 and 4 may be improved by special methods of working, and by more perfect fluxing than is usually secured in the foundry. This was to have been the subject of the next investigation; the ground had been cleared and the valuable alloys identified, and the work planned could have been rapidly and satisfactorily done had the opportunity been allowed. But from what can be gathered by the experience acquired the writer is inclined to suppose that careful mixture, thorough fluxing with phosphorus or other deoxidizing element, casting under pressure, rapidly cooling, and finally cold rolling or cold pressing as practiced by Dean,* copper-tin-zinc alloys, containing not to exceed $z+3t=30$ per cent. could be given a strength exceeding by 50 per cent. that obtainable under the ordinary conditions met with in the brass foundry. During the writer's experiments the copper used had a tenacity, as cast in small bars, of but one half that obtained by Mallett, who fluxed out the

* On the Mechanical Treatment of Metals; by R. H. Thurston; Metallurgical Review, 1877.

oxygen more completely. Similarly, in these preliminary trials, gun bronze broke at two-thirds the figure obtained frequently in making ordnance.

Alloys rich in copper receive most benefit by such special treatment.

The writer has found that ordinary bronze, composed of copper and tin, may be taken with rough approximation to accuracy as having a tenacity, as cast in the ordinary course of a brass founder's business, of about—

$$T_t = 30{,}000 + 1{,}000\,t;$$

where t is the percentage of tin, and not above 15 per cent. Thus gun bronze can be given about $30{,}000 + (1{,}000 \times 10) = 40{,}000$ pounds per square inch, if well made. In metric measures

$$T_{t1} = 2{,}109 + 70.3\,t,$$

giving for good gun metal $2\,109 \times 703 = 2\,812$ kgs. per sq. cm.

For brass (copper and zinc) the tenacity may be taken as

$$T_z = 30{,}000 + 500\,z;$$

where the zinc is not above 50 per cent.; and

$$T_{z1} = 2{,}109 + 35.15\,z.$$

Thus copper 70, zinc 30, should have a strength of $30{,}000 + (500 \times 30) = 45{,}000$ pounds per square inch, or $2{,}109 + (35.15 \times 30) = 3{,}165$ kilogrammes per square centimeter.

Referring once more to Figures 3 and 4, it is seen that a line of maximum elevation crosses the field marking the crest of the mountain in Figure 4, of which the "maximum bronze" is the peak. This line of valuable alloys may be practically covered by the formula:

$$M = z + 3t = \text{Constant} = 55,$$

in which z is the percentage of zinc, and t that of tin. Thus a maximum is found at about $t=0$, $z=55$, while the other end of the line is $z=0$, $t=18$.

Along this line the strength of any alloy should be at least

$$T_m = 40{,}000 + 500\,z.$$
$$T_{1m} = 2{,}812 + 35.15\,z.$$

Thus the alloy $z=1$, $t=18$ will also contain copper $=100-19=81$ and this alloy cu. 81, zn. 1, sn. 18 should have a tenacity of at least

$T_m = 40{,}000 + (500 \times 1)$
$= 40{,}500$ lbs. per sq. in.
$T_{1m} = 2{,}812 + (35.15 \times 1)$
$= 2{,}847$ kgs. per sq. cm.

The alloy: cu. 60; zn. 5; sn. 16; should have at least the strength

$T_m = 40{,}000 + (500 \times 5)$
$= 42{,}500$ lbs. per sq. in.
$T_{1m} = 2{,}812 + (35.15 \times 5)$
$= 2{,}988$ kgs. per sq. cm.

while the alloy z, 50; sn, 2; cn, 48; should give, as a minimum specification:

$T_m = 40{,}000 + (500 \times 50)$
$= 65{,}000$ lbs. per sq. in.
$T_{1m} = 2{,}812 + (35.15 \times 50)$
$= 4{,}570$ kgs. per sq. cm.

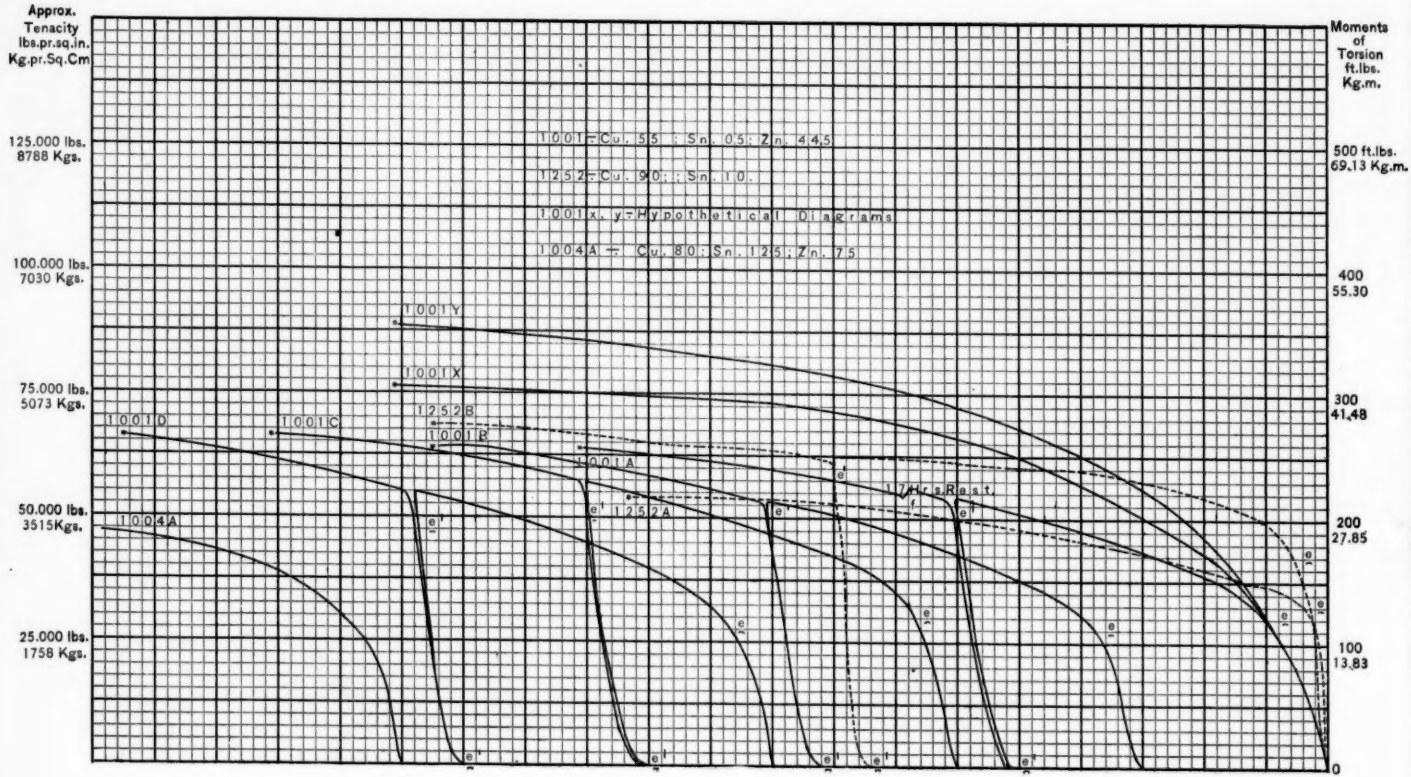
These are rough working formulas that, while often departed from in fact, and while purely empirical, may prove of real value in framing specifications. The formula for the value of T_m fails with alloys containing less than 1 *per cent. tin* as the strength then rapidly falls to $t=0$.

The improvement that may be expected to follow special treatment of some, and probably nearly all the more valuable of these alloys, may be inferred from the fact that Mr. S. B. Dean, in 1869,* increased the tenacity of cast gun bronze from 27,230 to 41,471 pounds per square inch (1,915 to 2,915 kilogs. per sq. cm.) by cold working, and General Uchatius, who introduced the Dean process in Austria, by chilling, increased the strength of his "steel bronze" from 35 092 pounds per square inch (2,260 kilogs. per sq. cm.), to 43,310 pounds (3,050 kilogs.);† the elastic limit remaining, however, unchanged at 5,680 pounds per square inch (400 kgs. per sq. cm). This metal then cold rolled by the Lauth method of Jones & Laughlin's, rose in tenacity to 71,937 lbs. with an elastic limit at 24,140 (5,066 and 1,700 kilogs. per sq. centimeter). This was the regulation alloy: copper, 90; tin, 10. When the tin was increased to 12 per cent the alloy was too hard to roll.

Colonel Rosset, of the Italian army, repeated Dean's work and extended it with the same result ‡

On the copper side of the maximum point on our map and model of the copper-tin-zinc alloys, is one that has been well studied and is of remarkable value. This metal was discovered by Mr. J. A.

* Ordnance Notes, No. XL, p. 255.
† Report on Manufactures and Machinery at Vienna, 1873; R. H. Thurston: p. 326.
‡ Resistenza dei Principali Metalli; Torino; 1874.


Approx. Tenacity lbs.pr.sq.in. Kg.pr.Sq.Cm
125.000 lbs. 8788 Kgs.
100.000 lbs. 7030 Kgs.
75.000 lbs. 5073 Kgs.
50.000 lbs. 3515Kgs.
25.000 lbs. 1758 Kgs.
Moments of Torsion ft.lbs. Kg.m.
500 ft.lbs. 69.13 Kg.m.
400 55.30
300 41.48
200 27.85
100 13.83
0
1001=Cu. 55 : Sn. 05: Zn. 44.5
1252=Cu. 90 : : Sn. 10.
1001x, y=Hypothetical Diagrams
1004A = Cu. 80 : Sn. 12.5 ; Zn. 7.5
1001Y
1001X
1252B
1001D
1001C
1001B
1001A
1004A
1252A
17 Hrs Rest.
e
e'
f

Tobin (U. S. Naval Engineer Corps), and described to the writer several years ago.* It consists of copper, 58.22; tin, 2.30; zinc, 39.48; it is hardly as strong as the alloy already described, but as cast had a tenacity of 66,500 pounds per square inch of original section, and 71,378 per square inch of fractured area (4,575 and 5,019 kilograms per sq. cm.) at one end of the bar which was, as usual, cast on end, and 2 per cent. more at the other. This alloy, like the maximum metal, was capable of being forged or rolled at a low red heat or worked cold. Rolled hot its tenacity rose ot 79,000 pounds (5,553 kgs. pr. sq. cm.), and when moderately and carefully cold rolled, to 104,000 pounds (7,311 kgs). It could be bent double either hot or cold, and was found to make excellent bolts and nuts.

A large proportion of the alloys on the copper side of the series marking the line $z+4t=50$ may be treated with equal or greater success, and there should be no trouble in securing copper-tin-zinc alloys of tenacities between 75,000 and 100,000 pounds per square inch (5,273 to 7,030 kilogs. per sq. cm.), by intelligent and skillful working. As I have elsewhere stated,* the metals used should be perfectly pure (Lake Superior copper; Banca or Australia tin; and New Jersey zinc); they should be protected from oxidation when fusing, carefully fluxed with phosphorus or other good deoxidizer, poured quickly into chills, cooled with the utmost rapidity, and the castings, when possible and safe so to work, rolled or forged either cold or hot. Should the work of the U. S. Board to Test Metals ever be resumed, this is likely to prove one of the most important and profitable lines of investigation. The results here given, it is obvious, are subject to revision after more work has been done, and the revision of data already obtained, the exclusion of unreliable and invaluable observations, and the formulation of more precise deductions will furnish employment for future investigators.

* By letter dated Feb. 6th, 1876, and verbally in 1875.

HOUSE ARCHITECTURE—PAST AND FUTURE.

From "The Builder."

When the late M. Viollet-le-Duc's work on the "Habitations of Men in all Ages" appeared, while no one could question the charm and suggestiveness of the book, it was regarded, and not unjustly, as including a good deal too much of the element of romance for a professedly historical sketch. The distinguished author might have been accused, in the words of Sheridan's great Parliamentary *bon-mot*, of having been, to some extent, "indebted to his imagination for his facts;" a criticism which, however true from the practical point of view, might with some readers have been rather a recommendation than the reverse. It was something new and unsual, at all events, to be asked to consider the history of the human habitation as a whole, apart from the mere practical view of it as a necessity of every-day life. There are many ways of regarding the house, and most of them, it must be confessed, are prosaic. There is the picturesque architect's point of view, which is the least prosaic, which, indeed, is sometimes so little prosaic as to fall into the opposite condemnation of being unpractical. There is the contractor's point of view of it, as a piece of construction out of which to make money. There is the sanitarian, who regards it as a place liable to develop smells and gases; and the investor of money, who regards the house as property worth so many years' purchase. And none of these ways of regarding the habitation are very exciting to the imagination. But take the subject at large and as a whole, and how interesting and picturesque it becomes. What a number of pictures arise in the mind, what a multitude of associations, all connected with and arising out of the one fact that mankind have required buildings to shelter them.

We look around in imagination on the various shapes which dwellings take in

* Metallurgical Review, 1877; Mechanical Treatment of Metals.

various parts of the world at the present day; all have their own significance—one had almost said their own picturesque value. In regard to the latter point there are certainly deductions to be made, when we think of the rows of brick walls in some of our towns; the three or four lines of oblong windows in the larger houses, and the "damnable iteration" of bay windows in the smaller class of street residences. Possibly we possess, in England, specimens of about the most uninteresting forms which the human habitation has ever assumed; at all events, we can hardly be outdone in this way. There has been a great deal of fine, stately, or picturesque and pretty house building on this island; but when our houses are dull looking and grimy, they are thoroughly so. It may be that, if we could only recognize it, there is, after all, a suitability to the circumstances, an occult fitness of things, even in the speculating builder's street house. It may be the true expression of the circumstances of the life that is lived in it—most dwellings are so in one way or another; but then how very unfit the fitness of things must be in that case.

"Mist clogs the sunshine;
Smoky dwarf houses
Hem me round everywhere;
A vague dejection
Weighs down my soul."

So says a poet of the day, and well he may. But it may perhaps be asked whether the mean houses are a cause or consequence of the dejection; and there may be as much to be said for the one view as the other. Life under natural and healthy circumstances will make for itself dwellings that will have something cheerful, characteristic, picturesque, about them. Country cottages in England have such character, and Swiss châlets, and log houses, perhaps, in freshly-cleared "backwoods." But where life has become a kind of mill, grinding down to the same shape all that is put into it, then the houses take a kind of mill form, too—a mill architecture is developed.

Not a pleasant or romantic aspect of the habitation, this; but, fortunately, this modern development, which will obtrude itself when the subject is mentioned, forms only a single, and may, if the present and the next age do their duty, form only a short-lived phase of house building. We cannot say positively, perhaps, that long-remote ages, as in Egypt, may not have seen an equally dull and depressing form of habitation for the many. In days when great kingly and priestly castes held sway and built enormous temples and palaces, it is only too probable that the average house of the population at large was but mean. There could be little to spend on it where so much was spent on unremunerative structures of vast size and costliness. Probably, the earliest house of all (after the cave, ready made) was of the nature of a tent; something easily removable; and the tent-like form and tent-like frailty of structure would impress themselves on more stationary domestic architecture for long after. From the tent-like form the next step would be to the hut form: the radical distinction between the two being that between sloping sides and a pointed finish, and upright walls with a complete roof, the superiority of which, in convenience and airiness and finished appearance, over the tent form, would hardly allow any more standing room for the latter; and then, when the hut form is established, comes the curious and long-drawn-out action and reaction of house and temple architecture upon one another. For, give the hut a verandah or porch, a deep projection of the roof with posts to carry it, and there is the temple in embyro, to begin with. But the temple was not confined to mere utilitarianism as a structure. The house for the god might be on the model of the hut, but it must be durable, rich, magnificent in scale and decoration. More costly and ponderous materials must be employed for it, and higher skill in design must be developed and displayed, at whatever cost, and that as a sacred duty. We see the most portentous development of this glorified hut architecture in Egypt; and a very striking idea it gives us of the lapse of time occupied in the development of that wonderful Egyptian-temple architecture, when we think through what long stages this transformation must have gone by which the grand columned temple grew out of the hut suggestion. This was under the sway of a mighty superstition of the supernatural, which crushed the

mere house, the mere human habitation, out of sight. The wrecks of the temples are still sublime in their decay; but, for all trace of the dwellings of the people, they might as well not have existed. In Greece the temple was still the main object of architecture; that the Greeks may have had convenient houses is possible; that whatever houses they built would have been graceful and beautiful, wherever there was any excuse for spending wealth over them, seems certain. But, at any rate, the best of them were so inferior in scale and importance to the temples that the dust of time has covered them. That Athens and other important cities contained thousands of habitations is historically known; but that cannot have been an important house architecture in the main which has left so little trace behind it. But under the less superstitious and more practical as well as more wealthy Roman, the house takes its revenge on the temple. One of the first Cesars was decreed the right to form on the façade of his house a pediment, the special feature previously of the temples of the gods. But this one fact (as it is traditionally reported to have been) was only typical of the place which domestic as well as civil architecture was beginning to assume with the progress of Rome in wealth and luxury. The pilasters and columns of the temple became attributes of domestic and civil architecture; the house rose to architectural grandeur and significance. The small rooms of the elegant houses of Pompeii, the provincial town, are decorated with semi architectural embellishments, which are the old temple architecture filtered down to the level of drawing-room prettiness. Where the superstitious or reverential side of human nature is in abeyance, where the commercial and practical side comes uppermost, there the dwelling takes an important place as architecture. The mansion is a sign that æstheticism and love of pleasure, the enjoyment of this life, has elbowed out superstition and asceticism; the healthy culture of this world has taken the place of the mystical contemplation of another. The religious spirit is not favorable to the development of the habitation; "Let us eat and drink, for to-morrow we die," has been a sentiment much more favorable to the growth of luxury and beauty in private dwelling houses than any spirit of religious aspiration, which would rather write "Mene, mene," on the walls of the most gorgeous apartment. The history of Christian architecture illustrates this: In the first great uprising of Christian reform there was, indeed, little account made of architecture or art of any kind; even the religious edifice, at first, received notice of disestablishment; the Most High "dwelleth not in temples made with hands." But this elevation above all material aids to faith could not be sustained for long. The Christian soon brought back the grand features of columnar architecture to the service of the temple, and other influences moulded them to new architectural forms and expressions, till in the Mediæval period the great architecture of the day is again, as in Egypt and Greece, all concentrated in the religious edifices. The house has architecturally all but disappeared, except in the form of the castle, made strong and massive for purposes of rapine, not to show forth the amenities of life. Even as late as Shakespeare's time, the church is distinguished as "the holy edifice of stone," obviously in contrast to the houses, the ordinary dwellings of his day, although, of course, there were exceptions for the great. Then followed the Renaissance, bringing back "the kingdom of this world" in unmistakable fashion with all its "pomps and vanities," its luxury and taste, its costly, intellectual, refined self-indulgence, and again domestic architecture took a leading place; again the habitation borrowed and adapted the features of Classic temple architecture to grace and adorn itself, though with more refinement and taste, and a more just and thoughtful æsthetic application of the materials, than in the Roman days.

From the Renaissance period the house has never ceased to play an important part in the architecture of Europe—so far, at least, as concerns the dwellings of the wealthier class. During the Georgian period in this country it sank lowest in regard to architectural development, even more so than the generally low level of architectural art might have seemed to render inevitable; it ceased almost to be architecture in the usual sense of the word, though very likely

those who designed the house of that day thought that a symmetrical cube of building with a porch projecting from one side of it represented all the architecture that a sensible man need desire for his house. In the main, however, the Italian Renaissance mansion has impressed its mark on the better class house of modern Europe more than any other form of architecture. Even the Elizabethan house is a record of modification of the Renaissance house (we are speaking now of architectural style, not of plan), combining the refinement of Renaissance style with some of the picturesqueness of Gothic—a combination which the French château of the early Renaissance period displays in still better and more graceful and fanciful form. In spite of the taste for Gothic houses which accompanied the general movement in favor of Mediævalism, there has always remained, even in this country, still more on the Continent, a prevalent feeling in favor of some variety of Classic style as the style for a large mansion, as being capable of taking an expression at once homelike and grandiose. We cannot, certainly, apply such an expression as "homelike" to the class of mansion with a large portico and colonnade like the end of a Roman temple imbedded in the house, which became the fashion for some time after the days of Wren and Inigo Jones. But when this temple end—this exaggerated and practically useless portico—is got rid of, our house architecture on the Renaissance model shows a good deal which is eminently successfal and suitable for its purpose.

This, however, is as to large and isolated houses. When we come to smaller houses, we find two well-marked divisions, street houses, and country cottages and small dwellings. Street architecture, as far as the average people's houses are concerned—anything worth calling street architecture, that is to say —has had a very short and broken life. There has been, probably, a great amount of really picturesque street architecture, in such cities as London, for example, which has perished entirely owing to its frail construction and materials; and in London, of course, partially by the Fire. What really made the sort of street architecture which we now regard as picturesque, such as that of Nuremberg and what is left of Chester, was in great measure the fact of cities being inclosed with walls, and therefore limited in area. Hence the narrow streets, the overhanging upper stories, which look so well in a sketch; they were the result of efforts to utilize every square foot of space inside the walls, in times when to live outside the walls might be really unsafe under certain circumstances. This influence no longer operates in the more civilized parts of the world; and there are influences operating in the opposite direction, operating to produce dull uniformity and regularity, and even to compel these qualities to a certain extent. Conviction of the danger in towns of improper building construction and inflammable materials has led to legislation which it seems to have been, and no doubt always would be, difficult to frame so as to be practically applicable to all cases, without almost compelling a certain uniformity of style and tending to promote the very opposite of a picturesque town architecture. It is difficult, but not impossible, to frame legislation which shall provide for sanitary conditions and security of construction without interfering too much with individual taste in building, or reducing our streets to dulness and uniformity. In the case of smaller houses in the country there has been always a great deal of picturesque character arising almost entirely from the fact that local buildings were made with local materials and in local methods. Each district had a character of its own in its house and cottage architecture, a character which was almost certain to harmonize with the landscape, from the very fact that the materials were local. The railway, the great leveler, is now doing much to modify and interfere with this local character and picturesqueness in country dwellings. Bricks can be easily brought where local stone would have been used by a former generation; slates are available at moderate expense where thatch would formerly have been considered quite an adequate covering. In these and other ways the changed conditions of modern life must influence the houses of the future, be they large or small, mansions or cottages, country or town dwellings.

What new development there is in house architecture at present is more in the direction of sanitary provision than of architectural design. Though so much remains to be done, there can be little doubt but that we are entering upon a very great and salutary change in this respect. The more enlightened section of public opinion has been aroused to the importance of the subject, and there can be no doubt that in future those who are able to build houses for themselves will not be content with their architect giving them the number of rooms they want and the architectural style they desire, but will want to know also that every precaution has been taken to remove or intercept every influence that may be prejudicial to health. The sanitary movement is fairly started, and we can have no doubt of its progress. The problem for future house architecture is to combine sanitary fitness with architectural beauty. It is certainly not superfluous to draw attention to this point, since, for whatever reasons, it is only too obvious that the taste for the sanitary and the picturesque seem to be far too antagonistic. Some members of the profession are vexed and irritated with the requirements of sanitation, and are prone to shuffle off the responsibilties thereof on to other shoulders. On the other hand, nearly everything connected with sanitation seems to be, at present, ugly as a matter of course. The very look of the publications of sanitary publishers "bewrayeth" them. "What a hideous-looking cover," said a visitor the other day, glancing at a pamphlet on our table. "Yes," we replied, "it is a sanitary publication." But the fault is on both sides. The sanitary reformer's work is genuine, but not beautiful. The picturesque architect's work may be beautiful in a certain sense, but unfortunately it is not always genuine, even on its own ground. It is a masquerade. The taste for it is the result of a half-view of the subject. Some architects think that the sort of thing which pleases them and their friends in their own sketch books now, will, if reproduced, equally please in its imitated form. It may for the moment, but it will not be sketched by other architects of future generations, for more reasons than one. Not only will the fashion of taste have changed, but a new way of looking at the subject of house building will have grown up with the increase of sanitary knowledge, and the picturesque house, with its extra gables and its twists and angles made for mere picturesqueness will not recommend itself to more practically-educated generations. For be it remembered that what we now admire as picturesque street architecture in old towns represents also about the most unhealthy form of domestic architecture that could be, in many cases. Materials subject to much decay, close and unventilated corners, a multiplicity of weak points for the invasion of wind and weather; these are among the characteristics of the old picturesque street views which we like to sketch. It may be found that a wider diffusion of knowledge as to the sanitary construction of dwellings will very materially alter the estimation even of the unconscious picturesqueness of the buildings of the pre-sanitary era. That which looks very pretty to those who have no practical acquaintance with the subject looks only puerile to those who have. We remember looking at Martin's picture of "The Plains of Heaven" in company with a yachting man. Our companion was indignant at the gilded barges on which the blessed were floating over the celestial sea. He should have hoped, he said, to find in heaven yachts of better build and sailing power than he had ever met with in terrestrial water. To the landsman the gilded barges might seem very sumptuously and picturesque; the nautical man only saw them as clumsy and "leewardly" craft. In like manner a generation more instructed in sanitary conditions of building may learn to look with a very different eye on what we now call "picturesque" town architecture, and associate it only with ignorance or carelessness of the sanitary conditions of building, of such primary importance in crowded towns.

Have we done, then, with picturesque house building? We hope not; only we must find a more practical and more beautiful species of picturesque. It must be a picturesque, that is, as the French say, *choisi*, chosen, selected, deliberately developed, not growing up spontaneously, not imitative of that

which grew up under different conditions. The picturesque of old towns was, as we have said, to a great extent imposed by the barrier surrounding the walled city of the past. The picturesque of rural houses arose from the employment of the materials and methods of the district with a kind of spontaneous freedom. The employment of the materials of the district in country buildings we have always urged where possible—that is, where they are practically suitable and adequate—as one means of securing harmony with the landscape. But the time is at least not far off when this spontaneous freedom must disappear even from rural houses. Intercommunication breaks down the barriers of provincialism in habits of speech and habits of living, and must do so too in regard to habits of building. It will become a recognized responsibility with landlords that even rural cottages must be well built and in accordance with the best and most healthy conditions in regard to materials and arrangement. In regard to town houses, we have officially recognized and legislated to this end already to a considerable extent, although the working of the legislation has not always been by any means satisfactory, partly owing, perhaps, to its attempting rather too too much in detail; the really desirable provisions of the law are too often evaded or only carried out at the point of much compulsion, while the suggestion which building legislation makes towards building every house according to a uniform pattern is only too well acted upon.

The result of these considerations in regard to average house architecture would seem to be that rural and town building will approach each other more in syle and manner than before. We want in the house architecture of towns (after the due carrying out of sanitary and constructive legislation) the recognition of the fact that it is not necessary that streets built in accordance with certain general practical legislation should therefore be marked by a dull uniformity; we want something of the variety and the special character which the exercise of individual taste should lead to, carried out always in subordination to the requirements of health and security from fire, and of general convenience; not, as in the old picturesque style of town, with an entire ignoring and trampling under foot of all these considerations. The rural dwelling must undergo some change in the opposite direction; some of its specially rustic character, its low unhealthy rooms and its little insufficient windows, must give place to better lighted and ventilated rooms, and the local traditions of building must in some cases give way to the use of better materials and methods. But all these conditions may be observed without reducing a country cottage to the appearance of a slice of a street cut out and put down in the country. It may be a country cottage still; but it must be a country cottage carefully and scientifically built, not one allowed to grow up in its place like a tree.

In regard to houses of the higher class we seem at present to vary between some form or other of the old Classic mansion, and a form of house which endeavors to be strikingly picturesque and homelike; the latter form much predominating among recent houses. The completely Gothic house, with high-pitched gables, has not had a long lease; it seems now to be getting quietly dropped. The ultra-picturesque house of the day we hold to be a sham to a great extent, though a natural reaction against the ultra-formality of an earlier part of the century. Many of these houses, which seem to affect to have been tumbled together in a heap, to be ingeniously accidental, will be laughed at or wondered at, perhaps pulled down and altered, as ugly things, by those will inherit them. Our impression is that a type of house design founded on the Renaissance is more likely to command lasting goodwill than any of these picturesque vagaries. But then it must be a type produced by improving on Renaissance types, not by bringing together a number of corrupt and debased details of the decadence of the Renaissance. The reason we lean to Renaissance, rather than to the picturesque for modern houses of the better class, is that the Renaissance house in its best form represents the domestic architecture of culture much more than does the irregular and studiously picturesque house. The house of a man of culture should appear studied, refined, "*choisi*"

in its architecture; not thrown together, an "*indigesta moles*," however picturesquely. The fault of the Renaissance houses of this country has mostly been that they were too formal and scholastic in arrangement and style. There is no need to follow precedent in that respect. We should wish to see the gentleman's house of the future no reproduction or imitation of houses of the past, no embodiment of cooked up picturesqueness, but a style of house recalling the most refined and thoughtful periods of society, stately without formality; homelike, but the home of dignity, education and refinement; the home of a cultivated man and woman of the world. The present very prevalent taste for "thrown-together" houses, heaped-up roofs, little windows, and so on, seems to us essentially a taste belonging to provincialism rather than to the character of a citizen of the world, as every educated man should be. We hope to see this rather puerile taste, pass away, and to see the house of the future take a more dignified and refined form, combining sanitary completeness, variety and charm in plan and arrangement (a much better kind of picturesque than simply cutting up the exterior skyline), and a certain palatial though not formal dignity—a habitation which would appear rather the result both of scientific and artistic culture.

THE QUALITY OF STEAM.

By JOHN W HILL, M. E.

A Paper read before the American Railway Master Mechanics' Association at the Providence Convention, June, 1881.

EXPERIENCE shows that steam always carries a certain percentage of water in suspension as it rises from the body of water of which it is formed.

This percentage will vary as between different forms of boiler, and the same boiler operated under different conditions.

The water so suspended in the steam is known as water entrained or as primage.

The raising of the water in a boiler by induction when a large steam pipe is suddenly opened, is entirely independent of the water entrained, and is not meant by any allusion to primage in this paper.

I believe it is a fact observed in chemistry that anhydrous gases cannot be obtained by direct vaporization, and that a special drying process is necessary to saturate or remove the liquid always entrained in the gas upon its first formation.

Saturated steam (that is, steam charged with such an amount of heat that any reduction thereof would produce condensation, and any increase thereof would produce super heat) is substantially a perfect gas and is usually so considered in all formulæ upon its action in a steam engine.

Our best information upon the temperature (heat) of saturated steam at various pressures is from the experiments of Regnault, *Comptes Rendus*, 1847, with which all steam engineers are sufficiently familiar to avoid the description of his apparatus or the circumstances under which his experiments were made, at this time.

It is proper to state, however, that the experiments of Regnault were to ascertain the relations of temperature, pressure and density of steam; and as a corollary to determine the specific heat of steam and water at various boiling points.

The determination of the relation of density and pressure was never made by Regnault, the only recorded experiments upon which were by Messrs Fairbairn & Tate several years later.

It is now well known that the steam engine is a heat engine, that the water which is vaporized to form steam is simply a vehicle in which we store up the heat of the fuel and which parts with a portion of this heat in transit through the engine; partly by conversion of heat into work, partly by conduction and radiation through the walls of the cylinder, and partly by the cooling

effect of the atmosphere on the piston rod.

No steam is expended in operating an engine; for the same weight of water as vapor which enters the cylinder by the steam pipe also leaves the cylinder by the exhaust pipe.

If we deliver one thousand pounds of steam at a given temperature to an engine through the steam ports, we shall draw off through the exhaust ports precisely the same weight of steam at a lower temperature. But during the passage of this steam through the engine a certain reduction of temperature has occurred, and the efficiency of the engine is a function of the limits of temperature between which the steam enters and leaves the cylinder, as enunciated by the junior Carnot more than fifty years ago.

To illustrate the efficiency upon the heat basis let us suppose an engine condensing—consuming—sixteen and one-half pounds of steam per hour, connected with a battery of boilers furnishing ten pounds of steam per pound of coal from the temperature of the feed. Let the thermal value of the coal be taken at 15,000 units, and estimate seventy-five per cent. of this, or 11,250 units, as contained in the steam above the temperature of feed water. Then the efficiency of such an engine would be

$$100 \times \frac{11250 \times 1.65 \times 772}{33000 \times 60} = 13.82$$

per cent., or of every hundred horse power resident in the heat expended in working the engine less than fourteen are utilized. The remaining eighty six horse power going out in the exhaust.

It is well known that the best economy we have any record of has been obtained from pumping engines, and that a duty of one hundred millions foot pounds per hundred pounds of coal is seldom attained. Now our condensing engine working upon sixteen and one-half pounds of steam, or one and sixty-five hundredths pounds of coal per hour, represents a duty of

$$\frac{33000 \times 60 \times 100}{1.65} = 119{,}988{,}000$$

nearly one hundred and twenty millions foot pounds.

From which it appears that *fourteen per cent.* is about a maximum efficiency with our present knowledge of construction.

The object of this paper is, however, not to discuss the economy of steam machinery, but to show the necessity for an exact knowledge of the thermal value of steam, in estimating the economy of engine and boiler performance.

To illustrate the effect of a lack of knowledge of the quality of steam furnished by boilers, let us suppose a temperature of feed of 212 F, an expenditure of coal of one thousand pounds, a consumption of feed water of twelve thousand pounds, and a boiler pressure by gauge of one hundred and twenty-five pounds.

The apparent evaporation from the temperature of feed in this instance is twelve pounds of steam to one of coal.

Without information to the contrary, and in accordance with the usual practice, we would accept this as the evaporation, and pronounce the result as extremely satisfactory.

Suppose, however, the temperature of the steam instead of being at saturation (1221.53 units), contained as a mean per pound only 1135 units; then the actual evaporation instead of being twelve to one, would be ten and eight-tenths to one, and this instance supposes an efficiency of furnace and boiler of nearly seventy-five per cent., and a thermal value of 15,000 units per pound of coal. In brief, supposes a quality of coal and efficiency of furnace rarely obtained.

None of the usual devices applied to steam boilers are capable of measuring the thermal value of steam, and recourse is had to special apparatus for this purpose.

Two distinct forms of calorimeter have been used; one the continuous calorimeter, in which the condensation of a certain small percentage of the steam is maintained during the entire trial of a steam engine or boiler, and the other the intermittent calorimeter, with which at stated intervals known weights of steam are drawn from the boiler or steam pipe, and condensed in known weights of water.

The continuous calorimeter consists usually of a coil of brass pipe or copper pipe of one quarter to half inch diameter of bore, containing thirty to fifty lineal feet. This coil is placed within a tin

can through which the circulating water passes from below upwards.

The upper end of the worm is connected with the steam pipe or steam drum of the boiler, and the lower end terminates in a neck which delivers the condensed steam into a receptacle mounted upon a carefully-balanced scale, with which the condensation is weighed from time to time, and dumped.

The circulating or condensing water is measured by tanks of known capacity, or through a Worthington meter, the error of which is known by test.

Standing thermometers are located as follows: one in the injection pipe, by which the circulating water enters the apparatus; one in the over-flow nozzle, by which the circulating water leaves the apparatus, and one in the neck of the worm from which the water of condensation flows.

Should there be an indication from the calorimeter data of super-heat in the steam, an additional thermometer should be inserted in the head of the worm or in the steam pipe leading to it, to measure the super heat independently and check the record of the calorimeter.

Steam flows through the worm and is condensed, the heat being transferred through the walls of the coil to the circulating water.

The temperature of the circulating water is elevated through a range represented by the difference of temperature of the inflow and outflow.

The temperature of the condensation as it leaves the calorimeter is read from the thermometer in the neck of the worm.

The temperature of the steam is the unknown quantity which we seek.

To illustrate the action of the continuous calorimeter assume a weight of steam condensed of one hundred pounds, a weight of circulating water expended in condensing it of 2,000 pounds, a temperature of inflow of 50 F, a temperature of outflow of 105 F, and a temperature of condensation of 60 F; then temperature of steam neglecting small effect of variation in the specific heat, is:

$$60+\frac{2000\times 55}{100}=1160 \text{ F.}$$

Assume the steam as it entered the calorimeter, at a pressure of 135 pounds by gauge or 150 pounds absolute, at which pressure the temperature of saturation is, according to Regnault, 1223.18 F. Then difference of temperature is 63.18 units, indicating that a portion of the water was entrained in the steam.

To estimate the percentage of primage we must bear in mind that the water in the boiler is first heated to a temperature of 362.56 F (corresponding to a pressure by gauge of 135 pounds), before vaporization takes place; and that an additional temperature of 860.2 units is necessary to vaporize the water so heated; and that the discrepancy in the thermal value of the steam applies to the temperature of vaporization, whence the water entrained as primage becomes

$$100\times\frac{63.18}{860.2}=7.35 \text{ per cent.}$$

The intermittent calorimeter consists of a water-tight vessel (preferably of wood to avoid transfer of heat to or from the contents thereof by conduction and radiation) mounted upon a sensitive scale, into which a known weight of water is drawn.

A small steam pipe, usually three quarters inch diameter, closely connected with the main steam pipe or steam drum of the boiler, dips into the vessel on the scale, and is provided with a cock or open-way valve to regulate the delivery of steam into the weighed quantity of water.

The temperatures are taken with a hand thermometer.

As suggested, a known weight of water is first weighed into the tank on the scale, usually some convenient quantity to estimate from, as one hundred or two hundred pounds, of which the probable condensation in the small steam pipe usually forms a part.

The amount of condensation which will collect in the steam pipe between observations will vary with the quality of steam, and must be blown out to clear the pipe before the weighed quantity of steam to be condensed is blown in.

The weight of water and condensation blown out of the pipe having been justified, the temperature of the contents of the tank is carefully taken with a reliable thermometer, and five or ten pounds of steam blown in and condensed. (The weight of steam condensed should be as

large as consistent with a limited temperature of the contents of the tank on the scale, to obtain a high range of temperature; since errors of weight are less liable to occur than errors of temperature, and the greater the range of the mercury the smaller the effect of errors of observation.)

The desired weight of steam having been condensed the flow through the pipe is promptly suppressed and a second temperature of the contents of the tank is taken.

The first temperature from the second temperature represents the range of the contents of the tank.

To illustrate the principle of the intermittent calorimeter let the following data be assumed:

Weight of condensing water,	100 pounds.
" " steam condensed.	5 "
Initial temperature condensing water.....	60 F.
Final temperature condensing water.....	115 F.
Range.....	55 F.

and the temperature of steam is

$$115+\frac{100\times 55}{5}=1228 \text{ F.}$$

Supposing steam as before at a pressure absolute of 150 pounds, the difference between the quality in the illustration and saturated steam is 4.82 units corresponding to a super heat of

$$\frac{4.82}{.475}=10.15 \text{ F.}$$

I have not detailed the construction and action of the two well-known forms of calorimeter with the expectation of adding any to your knowledge thereof, but to bring the processes fairly before you previous to calling your attention to some of the results of my experience with the instruments.

I shall not attempt, in the short time which, by courtesy, you allot me, to detail all my experiments with the calorimeter, as these are many and would frequently be simple repetition of results, but shall refer only to a few experiments to show the value of investigations of this class.

The first results we will examine are from a series of four experiments upon boilers set with smoke-preventing furnaces for the Cincinnati Industrial Exposition for 1879.

The first case was a return tubular containing 963.64 superficial feet of heating surface, and worked at a capacity equivalent to 2.77 pounds of steam per foot of heating surface per hour, which gave a temperature of steam of 960.46 units indicating, with a pressure by gauge of 38.75 pounds, a primage of 26.26 per cent.

The apparent evaporation from the temperature of feed (70.02 F.) per pound of coal was 7.59, but the actual evaporation from same temperature was only 5.6 to one.

The second case was a return flue boiler containing 519.45 superficial feet of heating surface, and worked at a capacity equivalent to 1.73 pounds of steam per foot of heating surface per hour, which gave a temperature of steam of 964 73 units, indicating with a pressure by gauge of 80.29 pounds, a primage of 29 13 per cent.

The apparent evaporation per pound of coal from the temperature of feed (166.01 F.) was 5.84, but the actual evaporation from same temperature was 4.14 to one.

The third case was a battery of two return tubular boilers containing 880.16 superficial feet of heating surface, and worked at a capacity equivalent to 3.20 pounds of steam per foot of heating surface per hour, which gave a temperature of steam of 1005.93 units, indicating with a pressure by gauge of 76.18 pounds, a primage of 23.19 per cent.

The apparent evaporation per pound of coal from the temperature of feed (169.11 F.) was 9.69, but the actual evaporation was 7.45 to one.

The fourth case was a direct tubular boiler containing 327.79 superficial feet of heating surface, and worked at a capacity equivalent to 2.96 pounds of steam per foot of heating surface per hour, which gave a temperature of steam of 1441.35 units, indicating with a pressure by gauge of 81.60 pounds, a super heat of 18.83 per cent.

The apparent evaporation per pound of coal from the temperature of feed (74.55 F.) was 8.80, but the actual evaporation upon the basis of saturated steam was 10.66 to one.

This boiler was set and worked simply

for test purposes, and was furnished with super-heating surface.

The continuous calorimeter was used in these experiments.

The next results to which I shall refer are the calorimeter tests for quality of steam during the trials of steam engines at the Millers' Exhibition, Cincinnati, 1880.

In this instance the experiments were all made with the same boilers operated under approximately the same conditions from day to day.

The boilers, two return tubular, contained 1327.24 superficial feet of heating surface, and were worked at the following capacities in pounds of steam per foot of heating surface per hour, for six different trials—2.53, 2.42, 2.32, 2.41, 2.42 and 2.63—with corresponding temperatures of steam of 1243.84 units, 1211.3 units, 1315.86 units, 1255.74 units, 1301.65 units and 1313.11 units.

Of these temperatures only one, the second, indicates primage, all others exhibit a slight super heat.

The primage at 92 54 pounds pressure by gauge in the second experiment was .46 per cent.

The percentage of super heat at 92.50 pounds pressure by gauge in the first experiment was 2.3; in the third experiment, with steam pressure at 91.65 pounds by gauge, 8.3 per cent.; in the fourth experiment, with steam pressure at 91.48 pounds by gauge, 3.34 per cent.; in the fifth experiment, with steam pressure at 91.44 pounds by gauge, 7.09 per cent., and in the sixth experiment, with steam pressure at 91.54 pounds by gauge, 8.06 per cent.

The continuous calorimeter was used in these trials.

The former results were from four different boilers of different forms and dimensions, and operated at different steam pressures and rates of evaporation, with a range in the quality of steam from 19 per cent. of super heat to 29 per cent. of primage, whilst the last six results were all from the same boilers, operated at different times, under approximately the same steam pressure and rates of evaporation with a range in the quality of steam from 8.3 per cent. of super heat to one-half per cent. of primage.

From which it appears that with the same boiler or boilers, operating under similar conditions, an approximately uniform quality of steam should be had, and that the quality of steam in any one instance cannot be assumed for another, unless the conditions are precisely alike.

The next results to which I shall refer are from three different trials upon the same boilers operated with similar steam pressures, and at different rates of evaporation.

The boilers, two in the battery, were of the return tubular variety, containing 932.02 superficial feet of heating surface.

During the first trial, steam was made at the rate of 4.09 pounds per foot of heating surface per hour, with a resultant temperature of 1153.09 units, indicating a primage at 92.59 pounds by gauge of 7.08 per cent.

During the second trial the boilers were worked at an evaporation equivalent to 2.86 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1199.04 units, indicating, with a pressure of 92.95 pounds by gauge, a primage of 1.92 per cent.

During the third trial the boilers were worked at a rate of evaporation equivalent to 2.90 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1174.17 units, indicating, at a gauge pressure of 92.28 pounds, a primage of 4.75 per cent.

These experiments were made with an intermittent calorimeter.

In all experiments exhibiting a small primage in the steam, as a super heat, the boilers were set to expose more or less of the steam room to contact with the hot gas.

The next results are from a series of three experiments with a small locomotive boiler, operated standing.

For the first trial the heating surface was 288.75 superficial feet, and ratio of heating to grate surface 25.9 to one.

The boiler was worked at a capacity equivalent to 8.49 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1150.98 units, indicating at 105.5 pounds pressure, by gauge, a primage of 5 per cent.

The apparent evaporation per pound of coal was 4.45, and the actual evaporation was 4.09 to one.

For the second and third trials the heating surface by the introduction of a water bridge into the fire box was in-

creased to 300.7 superficial feet, with a ratio of heating to grate surface of 41.67 to one.

During the second trial the boiler was worked at a rate of evaporation equivalent to 9.39 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1181.76 units, indicating at 98.25 pounds pressure, by gauge, a primage of 4.33 per cent.

The apparent evaporation in this case was 7.58 pounds, and the actual evaporation 7.25 pounds of steam to one of coal.

During the third trial the boiler was worked at a rate of evaporation equivalent to 9.77 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1259.29 units, indicating a super heat of 88.67 degrees F., at a pressure by gauge of 100.7 pounds.

The apparent evaporation was 6.41 pounds of steam per pound of coal, and the actual evaporation upon the basis of saturated steam was 6.65 to one.

The rate of combustion and evaporation was higher for the third trial than for the second, with a better quality of steam and a reduced economy.

In these trials the coal was burned within five or six per cent. of the total weights charged. and the calorimeter results can be fairly compared without correction.

The next result to which I will refer is from the boiler of a "Rogers" engine on the Ohio and Mississippi railroad, in a running trial from Vincennes to Seymour, made last July.

The heating surface was 984.33 superficial feet, and the rate of evaporation equivalent to 9.51 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1192.11 units, indicating a primage of 3.4 per cent. at a pressure by gauge of 125.56 pounds.

The apparent evaporation in this instance was 3.97 pounds per pound of coal, and the actual evaporation was 3.83 to one.

The poor economy of this boiler was largely due to the high rate of coal consumption (146.25 pounds per superficial foot of grate per hour).

With large grate areas and a reduced rate of combustion per superficial foot of grate per hour, the economy of locomotive boilers may be materially improved, as shown by the results obtained with the "Wooten" boiler on the Philadelphia and Reading railroad.

I am aware that some of my professional friends are not seized of my faith in the reliability of calorimeter results; but I am unable to obtain from them any better objection than that some modifying data has been overlooked or neglected in those cases which do not meet their approbation. However, when they agree, as they invariably do, that condensed steam and condensing water may be accurately weighed, and that approximately accurate temperatures may be had with good makes of thermometers; then I can conceive no other objections to accepting the results of calorimeter experiments than the personal errors of observation which pervade all mechanical investigations.

If the power of steam engines is to be measured by the indicator, or the less reliable dynamometer or friction brake; if the economy of boilers and engines is dependent upon the accuracy of weighing scales; if steam pressures are to be taken from spring gauges and temperatures read from mercurial thermometers, and such results are held to be reliable for absolute and comparative effect; then the same reliability must, in simple justice, be accredited the calorimeter; for it depends solely upon correct weights and temperatures, and involves no complex or uncertain quantities in the operation.

A CORRESPONDENT describes the following as a filler for porous hard woods: "Take boiled oil and corn starch, and stir into a very thick paste. Add a little japan and reduce with turpentine. Add no color for light ash. For dark ash and chestnut, use a little raw sienna; for walnut, burnt umber and a slight amount of Venetian red; for bay wood, burnt sienna. In no case use more color than is required to overcome the white appearance of the starch unless you wish to stain the wood. This filler is worked with brush and rags in the usual manner. Let it dry forty-eight hours, or until it is in condition to rub down with No. 0 sand paper, without much gumming-up, and if an extra fine finish is desired fill again with the same materials, using less oil, but more of japan and turpentine.

RECENT PROGRESS IN THE MANUFACTURE AND APPLICATIONS OF STEEL.

By PROF. A. K. HUNTINGTON.

From the "Journal of the Society of Arts."

At first sight, the title which I have given the paper I am about to bring before you this evening, might lead some to suppose that it was intended to deal with very recent events, such as might have occurred within the last few months, or say a year. Such anticipations would be fully justified were I to address you on recent progress in the applications of electricity, for this offspring of intellects of our own era makes marvelous progress from day to day, until one feels tempted to concede to it a position in the universe similar to that occupied in the human body by nerve force. In fact, the want of continuity between our nerve system and what we may call that of the world is fast becoming less and less. We can already flash our ideas and our voices to the farthest parts of the earth, and the reproduction of the images of material objects by similar means seems to be in a fair way of accomplishment. But the subject of our attention to-night had its commencement in times so remote as to be far beyond the reach of human record, and its rate of progress may be measured by that of the world itself in the Arts and Sciences.

Improvements in the Arts and Sciences have gradually modified the methods of producing iron and steel; and, in their turn, the Arts and Sciences have felt the re-action; for all improvements in the manufacture of iron and steel have been not so much in the production of a better quality of article, but in the cheapening of production, by the application of the principles indicated by the progress of science, and by the use of superior machinery. The direct result of this cheapening has been to extend the applications of the products in the Arts. To appreciate this, let us glance back, and see by what means steel was produced up to the year 1855, and what were its applications, and then trace out the causes of the changes which have since taken place in these respects.

The discovery of steel appears to have naturally followed that of the means of reducing iron from its ore. In all primitive methods of iron smelting, steel, in more or less quantity, is inevitably produced. Such methods have been carried on in India and Africa from time immemorial to the present day. A similar furnace has, for several centuries, been employed in Catalonia, in Spain. The comparative cheapness of iron manufactured in other countries by improved methods, is, however, rapidly causing this furnace to pass out of use.

I propose now briefly to describe to you the process in the Catalan furnace, as it is called, in the form into which it last developed in Spain and the South of France, in order that we may clearly understand the essential differences between iron and steel, both as regards their composition and properties, and also the conditions requisite in the production of each.

Mode of Conducting the Process.—The ore is crushed by the hammer, and divided by sifting into lumps ("mine") and very coarse powder ("greillade"). The furnace being still red hot from the last operation, it is filled with charcoal nearly to the twyer, the hearth is then divided at a point about two-thirds distance from the twyer into two parts by a broad shovel; on the blast side a further quantity of charcoal is added, whilst that on the other side having been rammed down firm, ore is added, so as to fill that part of the furnace; on this is placed moistened charcoal dust, except at the top. A good blast is then turned on, and if the whole is in good order, jets of blue flame at once issue from the uncovered portion of the ore. After a few minutes the pressure of the blast is lowered to 1.5 in. of mercury. At intervals during the pro-

cess—which lasts about six hours—the blast is gradually raised until it reaches about 3 in., the maximum usually employed.

During the whole of the process, at short intervals, "greillade" and charcoal are added, and well moistened with water, to prevent too rapid combustion. After about two hours from the commencement, the wall of "mine," *i. e.*, ore in lumps, is pushed well forward under the twyer, and more "mine" is thrown into the space thus made; this part of the process is also subsequently repeated at intervals, until sufficient has been added to form a lump of iron or *masse* of the required size. From time to time slag is removed by opening the tap hole. At the completion of the process, a mass of metal is obtained weighing about 3 cwt., which invariably consists partly of soft iron, and partly of steely iron and steel.

Reactions in the Furnace.—We have seen that in the one part of the furnace only charcoal and "greillade" are introduced, and in the other only lumps of ore. That the ore should be in lumps at that part is a very important point, for in this way the hot reducing gas, carbonic oxide (CO), generated by the action of the blast on the charcoal, is able to pass freely through the mass of the ore, the effect of which is that the water of hydration and the moisture are first driven out by the heat, and then the ore having become easily permeable, the carbonic oxide reduces it to metallic iron, thus, $Fe_2O_3 + 3CO = Fe_2 + 3CO_2$. There are, however, several stages in this reduction, magnetic oxide being first formed thus, $3Fe_2O_3 + CO = 2Fe_3O_4 + CO_2$; and protoxide is next formed before metallic iron is obtained thus, $2Fe_3O_4 + 2CO = 6FeO + 2CO_2$, and $6FeO + 6CO = 3Fe_2 + 6CO_2$. At the same time that these reactions are going on, the ore has become impregnated with carbon, derived from the decomposition of the gases with which it is charged. That this would be the case, the experiments of Mr. Lowthian Bell and others can leave no manner of doubt.

On the twyer side, where are placed the charcoal and "greillade," the latter, as the charcoal is burnt away, descends rapidly, and, to a considerable extent, doubtless, escapes reduction, for the arrangement of the blast is such that most of the reducing gas is projected on to the lumps of ore and does not pass up through that portion of the furnace occupied by the charcoal and "greillade," which, besides, are constantly damped. This "greillade" is much richer in silica than the larger pieces, from which it results that the quantity of slag will vary with the "greillade" added. It is always very rich in oxide of iron.

Now, what happens in this process appears to be this: carburized iron is produced by the gradual reduction and fusion of the lumps of ore, and this, coming in contact at the bottom of the furnace with slag, very rich in oxide of iron, the carbon of the one combines with the oxygen of the other, and the result is that iron containing more or less carbon is produced, according as much or little oxide was present.

The obvious conclusion would be, that the less there was of "greillade" present the more steely would be the iron; in practice this is found to be the case. This circumstance would naturally suggest the total suppression of the "greillade," when it was desired to produce steel. This would, however, be impracticable, for it is necessary that some of the oxide of iron should remain unreduced in order to flux off the silica, which occurs in considerable quantity in the ore. In the blast furnace, this difficulty is got over by employing lime; but lime at the temperature of the Catalan furnace would not produce a sufficiently liquid slag.

All that can be done, then, is to employ every available means to prevent decarburization. Accordingly we find that when steel is required, in addition to using less "greillade," the slag is tapped out more frequently, so that the lump of iron, as it forms, may remain as little time as possible in contact with it. The bank of ore is exposed for a longer time to the reducing and carburizing gases, and is pushed more gently towards the twyer, so as not to become decarburized by the air which has not had time to combine with the carbon of the charcoal. Lastly, manganese should be present. It is found that the presence of manganese has a very important influence, which is probably due to its power to replace iron in the slag. A slag

containing manganese is more liquid than if it contained iron alone, and, according to Frangois, has not the same tendency to cause decarburization at the temperature of this process.

In order, then, that steel may be produced by this process, every precaution is taken to cause as much carburization as possible; the unavoidable presence of oxide of iron in the slag, and the low temperature, effectually preventing the formation of cast iron; the former, indeed, making it very difficult, as we have seen, to obtain steel.

It might be said, why not increase the temperature, so as to obtain a liquid slag without using oxide of iron? If the temperature were increased, cast iron, instead of steel, would be produced; in fact, that is exactly how cast iron first came to be obtained in blast furnaces.

I have gone rather fully into this process, because the principle of it is not always well understood. Rightly looked at, it explains how steel was first obtained, and what the essential conditions are, in the production of steel. When, owing to the increased size of blast furnaces, and the consequent increase in temperature, cast iron became the only product, it naturally followed that this substance should be treated with a view to the production of steel. This was first effected in the fining hearth, and formed an important industry in Styria, Carinthia, the Tyrol, and other places, in some of which it is still carried on.

The operation was conducted in a finery, similar in construction to those employed in the production of iron—in fact, iron and steel are often produced alternately in the same finery. This furnace, in its simplest form, consists essentially of a shallow quadrangular hearth, formed of cast iron plates. In one side is a twyer, inclined at an angle of 10° to 15°. The bottom is kept covered with a layer of charcoal.

In the Siegan district, a piece of pig iron, weighing 50 lbs. to 60 lbs., is placed on the hearth, having been previously heated; the hearth is then three-parts filled with burning charcoal; on it is placed a portion of the cake produced in the last operation, and which has been kept hot in burning charcoal, at the back of the furnace. The remainder of the hearth is then filled up with charcoal. The other six or seven pieces into which the last cake was divided, are placed on the top. In this process the production of steel, and the reheating of that obtained in the last operation, preparatory to working it under the hammer, are conducted together. The blast is turned on. The piece of pig iron forms into a pasty mass; cinder, rich in oxide of iron, produced during the latter part of the preceding operation, is then thrown in; a second piece of pig iron, weighing about 100 lbs., is added, and, afterwards, four or five pieces of spiegeleisen, weighing each about 100 lbs., are successively added. (Spiegeleisen is cast iron, containing manganese, in this case about 4 per cent.) If the metal is found to be too much decarburized, more spiegel is added. The cinder is usually allowed to rise 2 inches or 3 inches above the cake of metal, any excess being tapped off. There are several modifications of this process, but I have said enough to make the principle clear. In this process, as in the Catalan, it is impossible to obtain a homogeneous product. The principle in both is essentially the same, viz., decarburization by oxide of iron. In the finery process, in addition to the oxide added in the form of cinder and scale produced during the working of the metal under the hammer, some results from the reheating, which we have seen is carried on at the same time. In this process manganese also plays an important part, and we shall see that in every process for the production of steel, manganese is used with great advantage.

With one notable exception—the cementation process—the early methods for the production of steel were simply modifications of the methods for producing malleable iron. Accordingly, we find that the introduction of the puddling process, by which malleable iron is produced in a reverberatory furnace, was soon followed by a similar process for the manufacture of steel.

The essential difference between the finery and the puddling process consists in the use of a reverberatory furnace, the manipulation of the metal and the regulation of the temperature being thereby greatly facilitated. The decarburization is effected by the addition of oxide of iron produced during rolling, and partially by the air which enters the fur-

nace as the metal melts slowly down; manganese is added during the process. It is important that the temperature should be kept low. It is difficult to weld this steel perfectly; this is probably due to the temperature at which the steel has to be worked, being too low to make the cinder sufficiently liquid to enable it to be squeezed out under the hammer to the same extent that it is in the case of malleable iron. This difficulty has, however, been got over by completely fusing the steel before working it, so as to enable the slag to completely separate. In this form metal manufactured by this process has been largely used by Krupp. This defect is common to all steel which has been produced without fusion.

The same principle as that which regulates the production of steel by the foregoing methods is taken advantage of in the Uchatius process, which was patented in 1855.

Pig iron is first granulated by running it while molten into cold water. The granulated metal is then mixed with about 20 per cent. of roasted spathic ore, crushed fine; the mixture, to which a little flux has been added, if necessary, is then fused in clay crucibles. If very soft steel is required, some wrought-iron scrap is added.

Lastly, in this category we have a process which consists in heating cast iron, but not so as to soften it, in oxide of iron, in the form of ore or iron scale. In this way partial, or even total, decarburization of the metal can be produced at will.

So far we have seen, then, that the difference between iron and steel is merely one of degree depending on the amount of carburization. The methods we have considered, in fact, are only modifications of those practiced for the production of malleable iron.

We will now pass to the brief consideration of the different methods of procedure for the production of steel, which, however, I think I shall be able to show naturally resulted from the observation of phenomena occurring in the first process we have had under consideration.

These processes have for their object to impart a certain amount of carbon to malleable iron. The Hindoos have practiced one of them from time immemorial. They place in unbaked clay crucibles of the capacity of a pint, a piece of malleable iron, and some chopped wood, and a few leaves of certain plants; the top of the crucible is then closed with clay, and the whole well dried near a fire. A number of these crucibles are then strongly heated for about four hours in a cavity in the ground, by means of charcoal and a blast of air forced in by bellows. There is some reason to believe that an excess of carbon, over that required to produce the hardest steel, has to be added, in order to fuse the metal at the temperature which can be commanded in these furnaces. Before being drawn out into bars, the cakes of metal obtained in this way are exposed in a charcoal fire during several hours, to a temperature a little below the melting point, the blast of air playing upon them during the time. The object of this is, doubtless, to remove the excess of carbon.

In 1800 a patent was taken out by David Mushet, for a process in every respect analogous to that just referred to. He appears, however, to have applied it to the manufacture of a metal low in carbon, and therefore intermediate between iron and steel, partaking, in a certain degree, of the properties of both, corresponding, in fact, to what we have referred to as steely iron. Since this metal must have been in a state of fusion, Mushet must have brought to bear upon it a very high temperature. The manufacture was conducted in crucibles.

In another method referred to by Biringuccio, in 1540, steel is produced by keeping malleable iron in molten cast iron until it became pasty, and on examination was found to possess the properties of steel. In connection with the theory of steel manufacture this process is of great interest. It shows that iron in a strongly-heated condition is capable of absorbing carbon by direct contact, unless we suppose that carburization is effected by dissolved gases, which is possible, for Graham and others have proved that iron can occlude gases even when it is in a solid state.

If we admit that the mutual affinity of carbon and iron, is such as to cause them to unite at the temperature of molten cast iron, it is then not difficult to conceive how the whole mass becomes

carburized without the intervention of occluded gas. In asking you to concede that the surface of the iron enters into combination with the carbon in this way, I am strictly within fact, as shown by the Hindoo and Mushet processes. A marked case of this kind occurs when sulphur and silver or copper are brought together at the ordinary temperature, combination takes place.

The particles of iron at the surface having taken up carbon, their affinity would be satisfied, but the affinity of the atoms contiguous and beneath would at once come into play, and would only be satisfied by an equal division of the carbon between themselves and those on the surface.

Imagine a man carrying four cannon balls, his strength just sufficing for the task; he encounters an enemy equally strong, but who is unencumbered, and, therefore, in the possession of his whole strength.

For the sake of simplicity, we will call the man carrying the cannon balls A, and the other B. B first applies his whole strength to wrest one ball from A, and succeeds, for the chances are 4 to 1 in his favor, A holding the ball only with a fourth part of his strength, whereas B applies the whole of his. B then tries to obtain another ball from A, and again succeeds, for the force he applies in relation to the resistance offered by A, is as 3 to 2. A and B are now on an equal footing; each is capable of taking up two more cannnon balls, should the opportunity present itself.

Now, let the cannon balls be represented by the carbon atoms, and A and B by the surface and the inner contiguous particles of iron, then the bath of molten cast iron will form a reservoir from which A can re-charge itself. In the meantime other particles, C, will have deprived B of part of its carbon, just as B did A, and B will, therefore, be again in position to obtain carbon from A.

The same reasoning would apply to each successive layer of metal throughout the mass, that on the surface taking up carbon continuously from the bath of molten metal, until, if the process were continued long enough, the malleable iron would become converted into cast iron of the same composition as that in the bath into which finally it would dissolve.

We now come to what is called the cementation process. It is not known when this process was first used. It was well described by Reaumur in 1722. In this method bars of iron are kept at a glowing red heat, surrounded with charcoal in boxes, into which the air is prevented from entering. The operation lasts from seven to ten days, according to the quality of steel required. These bars are never uniformly carburized, and, besides, they contain cinder, as the metal has never been fused. The process had been a long time in use, however, before it occurred to any one to fuse the steel and make it homogeneous. This was done by Huntsman, about 1760. It was the first time that steel had ever been intentionally obtained in a molten state, unless we except the Hindoo process, but the fused product in that case was probably too highly carburized to constitute steel. I have already premised that the addition of carbon to malleable iron, in order to produce steel, resulted from the observation of what took place in the processes first described. It was, in fact, a matter of common observation that iron, no matter whether solid or molten, kept in contact with carbon, became more or less steely. What more natural then than to endeavor to produce steel directly in this way?

By all the processes we have so far reviewed, good steel could be produced, but only in small quantity and at great expence. The applications of steel were, in consequence, very limited; in fact, practically, its use was confined to implements with a cutting edge.

In 1845, Heath patented a process which, had it been successful, would have given him the power of producing steel in quantity. He proposed to melt scrap iron in a bath of molten pig iron in a reverberatory furnace heated by jets of gas. There were two conditions wanting in this method, which caused it to be a failure, viz., a sufficiently high temperature and the power to easily regulate the character of the gases employed. Nevertheless, in this suggestion is to be found the germ of one of the two most important processes of the present day. By the foregoing remarks I do not in-

tend to imply that the idea of mixing wrought and cast iron together to produce steel was originated by Heath. On the contrary, as we should expect, this idea was a very old one. In 1722, Reaumur tells us that he succeeded in making good steel in a common forge in this way. As far as I am aware, however, Heath was the first to suggest the use of a reverberatory furnace and gas for the purpose, and that is the important point.

It may here be pointed out, that the manufacture of steel by this method does not depend by any means entirely on the adjustment of the relative proportions of wrought iron and pig iron, as appears sometimes to be thought by those not specially acquainted with the process. There is a good deal of oxidation going on during the operation, which results in the elimination of an equivalent proportion of carbon from the pig iron.

The dominant idea in treating cast iron for steel had always been to refine the metal by the action of atmospheric air, and this was effected by causing a current of air to impinge upon the surface of the metal, by means either of blowing apparatus or the drawing action of a chimney stack. What more natural than that it should occur to some one to refine iron by blowing air into it, instead of merely on its surface? We find that this idea did actually occur to several persons, widely separated, in the year 1855. It is a noteworthy fact that a very large number of what we call discoveries or inventions are made simultaneously, and independently, in different parts of the world by people who previously had probably never heard of one another.

It would seem as if the records of observations accumulated in men's minds, and in books, until they naturally pointed to certain conclusions. The man who follows up these conclusions, and applies them in practice, is not always the one who first perceived them. To carry out what appears to the world at large as new ideas, requires great strength of purpose, and such a combination of circumstances as to afford an opportunity.

In this year (1855) a patent was taken out by John Gilbert Martien, for refining iron, by forcing air through it as it flowed from the blast furnace or cupola, along runners, to the puddling furnace. This conception was a very important one in the sense that had not others been working in exactly the same direction the same time, it would probably have assisted in working out the problem involved. The process, as detailed in the patent, was impracticable, and shows internal evidence of not having been worked out on a manufacturing scale.

Just after this patent was taken out, we find George Parry, of the Ebbw Vale Works, making the experiment of forcing air through molten cast iron, on the bed of a reverberatory furnace, by means of perforated pipes imbedded in the fire-clay bottom. Vigorous action is stated to have taken place, but, unfortunately for the experimenters, the metal, through an accident, escaped from the furnace, and the further trial of the process was discouraged by the managing director. There can be no manner of doubt that had this experiment been continued very important results would have ensued. As the Ebbw Vale Company had bought Martien's patent rights, it would appear that their experiments were really based on his idea. Of this I am not, however, certain, as I am not aware of the date at which they made the purchase.

Two or three months after these experiments, Hery Bessemer took out his now celebrated patent for the production of cast steel, by blowing air through molten cast iron; it should be clearly borne in mind that he had been, for considerable time, previously engaged in experiments on the subject.

Whether Bessemer originally started with the idea of refining pig ready for puddling, and, in the course of his experiments, made the discovery that by the action of the oxygen of the air on the carbon of the pig iron, such an enormous heat was produced that the resultant iron was obtained in a molten state —a thing never before accomplished—I do not know. The only alternative is that he arrived at the same conclusion, by inductive reasoning, which, all things considered, is very improbable.

Bessemer first carried out his process in crucibles, placed in furnaces and arranged so that the contents could be tapped from the bottom into moulds.

Steam or air, either separately or together, and by preference raised to a high temperature, was forced down into the crucible through a pipe. The patent goes on to state that steam cools the metal, but air causes a rapid increase in its temperature, and it passes from a red to an intense white heat.

It was, and still is, to a less extent, an infatuation of patentees, to employ steam in the place of air. Bessemer soon discovered the essential difference which exists in practice though not realized by the excited imaginations of the majority of would-be inventors. Bessemer at first used extraneous heat to start the process, if not, indeed, during its progress, which shows that he was not then aware that the heat created by merely blowing in air would be sufficient.

In his next patent taken out shortly after, however, he dispenses with the furnace round the crucible, and instead of tapping the crucible from the bottom, he mounted it on trunnions, and by tipping it up by machinery, poured the contents from the mouth. This apparatus, devised by Bessemer, is essentially the same as that used at the present day. The way in which he worked out the process in every detail to a grand practical success, in such a short space of time, shows him to have been possessed of a mind of great powers of conception. Having the facts before him, he drew the right conclusions from them with unerring judgment, and from one experiment passed to another suggested by it, until with indomitable perseverance he succeeded in bringing about greater progress in the manufacture of steel in a few months than had occurred in centuries before.

It was very soon found that to produce steel by this process which would work properly, manganese, if not originally present, would have to be added. In the absence of manganese, sulphur and oxygen, in anything more than very minute quantities, makes the steel crumble when worked at a red heat; it is said to be "red short." In the case of the oxygen, the manganese combines with it, and passes it into the slag; but, with sulphur, the reaction is different; its injurious effect is simply counteracted by the manganese; it is not removed from the steel.

At first manganese was only employed in the form of spiegeleisen—a variety of cast iron, containing manganese. The use of this substance was first suggested by Robert Mushet. When, however, it was attempted to produce very soft steels, a practical difficulty arose. If sufficient spiegel was added to impart the requisite quantity of manganese, then too much carbon would have been introduced. This ended in attempts being made to produce spiegel richer in manganese. By suitably adjusting the conditions in the blast furnace, this was soon easily accomplished; and instead of spiegel containing less than 10 per cent. manganese, a 20 per cent. spiegel was produced.

At the suggestion of Bessemer, attempts were made to obtain a still richer alloy. This was accomplished by reducing rich ores of manganese with cast iron in crucibles or in a reverberatory furnace. These richer alloys are known by the name of ferro-manganese. They are employed with great advantage when very mild steel is being manufactured.

By adding at the end of the process a known quantity of spiegel or ferro-manganese, containing a known quantity of carbon, steel of any required hardness could be obtained. There was but one important drawback to the Bessemer process, and that was that phosphorus was not in the least degree eliminated by it; consequently, only the best ores could be employed, which considerably increased the cost of production over that which it would otherwise have been. I will refer to that point again presently.

The year which saw the birth of the Bessemer process was doubly remarkable, for it was at that time that the regenerative system of heating was first introduced by Dr. Siemens. Nothing can be simpler than the principle involved in this method, yet it was destined to play a most important part in the progress of the arts. The idea was to store up the heat escaping in the waste gases from furnaces, and to employ it to raise the temperature of the gas and air previous to their combustion in the furnace. This was accomplished by causing the spent gases to pass through two chambers filled with loose brickwork. When these chambers have become heated to a high temperature, the

waste gases are made to pass through two other similar chambers, and the air and gas necessary for combustion in the furnace are caused to pass through the highly heated regenerators. By causing the ingoing gases to pass alternately, at suitable intervals of time, through each pair of regenerators, a very high and, at the same time, uniform temperature can be obtained in the furnace, without any greater consumption of fuel than in the older methods. The success of this process depended entirely on the fuel being first converted into a combustible gas. This was done in a chamber to which only sufficient air is admitted to convert the carbon into carbonic oxide, which is then conducted by tubes to one of the regenerators to be heated, and thence to the furnace, where, coming in contact with air which has been passed through the other regenerator, it burns, giving out intense heat. It is at once apparent that we have here the very conditions which were wanting to make successful the process patented by Heath in 1845, for not only we have the high temperature which could not then be obtained, but it has become easy to create at will, by regulating the relative proportions of combustible gas and air, either an oxidizing, a reducing, or a neutral flame.

There are two methods now in use for the production of steel in the reverberatory furnace or open hearth as it is called. In France, pig iron and scrap steel are fused together; in England, pig iron is decarburized by means of iron ore, some scrap, however, being generally added for the sake of utilizing it. As in the Bessemer process, the necessary amount of carbon is imparted to the metal by the means of spiegeleisen or ferro-manganese. This process has been largely employed for the production of ship and boiler plates. It has the great advantage that the metal can be kept fluid on the hearth, and its composition adjusted until it is exactly that required.

In 1876, a patent was taken out by M. Pernot, in which it was proposed to produce steel on an open-hearth furnace with a revolving bed, inclined at an angle of 5° or 6° to the vertical. Pig iron previously heated to redness is placed in the bed of the furnace and covered with scrap steel. The bed of the furnace is then made to revolve slowly, the pig gradually melts, and the scrap is alternately exposed to the strong heat of the flame, and then dipped under the molten pig iron. In this way the fusion is very rapid comparatively, the whole mass becoming fluid in about two hours. The process is then completed in the ordinary way. When repairs are necessary, the bed on its carriage is drawn out.

In practice, it is found that these furnaces require very frequent repairing. With the view to make this easier, M. Pernot has arranged a movable roof, which has besides the additional advantage of reducing somewhat the strain on the structure, occasioned by such great variations in temperature. M. Pernot informs me that he has just taken out a patent for an arrangement of his furnace by means of which he can employ gas under pressure, and that within the last few months he has obtained by this means results which have never been equaled before. He states that, in a seven-ton furnace, he has obtained five charges in twenty-four hours. This, at any rate, contrasts favorably with the figures given by Hackney, in 1875. He says five charges, of about four and a-half tons each, are got out in each twenty-four hours; the coal used being about eight to eight and a-half cwts. per ton of steel. The averages obtained with furnaces of similar design, and working under similar conditions, but with fixed beds, he states to have been just about half, and the coal used per ton of steel to have been eighteen cwts. Mr. Holley, of New York, has recently stated that they are getting with the ordinary Pernot furnace a seventeen-ton charge in six and a-half hours, all cold stock, except five tons pre-heated scrap.

The Steel Company of Scotland tried the Pernot system and abandoned it. They appear to have come to the conclusion that, owing to the great trouble and expense in keeping the furnaces in repair, the system possessed no special advantage over the ordinary Siemens furnace. If I am not mistaken, however, the Steel Company of Scotland were using these furnaces for soft steel for ship plates, whereas, in the instances referred to, rail steel was being manufactured. This is an important differ-

ence, the temperature in the former case requiring to be much higher than in the latter, the carbon being less, and the metal, therefore, more infusible; consequently, the wear and tear and attendant expenses would be proportionately greater. Be that as it may, it is beyond dispute that this system has achieved a considerable measure of success abroad, which will probably increase, as modifications, such as I have referred to, are gradually effected to reduce wear and tear, and facilitate repairs.

We now come to the Ponsard furnace. It aims at combining the advantages of the Bessemer and open-hearth processes. The furnace is so arranged that, by giving it a half revolution on its oblique axis, the twyers with which it is supplied may be brought either beneath or above the surface of the bath metal. By these means the metal can be rapidly decarburized nearly entirely, as in the Bessemer converter, and then, by removing the twyers from beneath the metal, the final adjustment of the carbon can be made as in the Siemens process. The only difficulty experienced in working out this idea to a practical success appears to be the rapid destruction of the twyers. This obstacle is certainly a very great one, and it may possibly be found insurmountable.

It may here be remarked that some firms in France, and, indeed, in England, too, claim to be able to produce steel of any required composition and characteristics with equal exactness by the Bessemer process as by the Siemens. There can be but little doubt that much can be done in this way by the Bessemer process where the work is systematically and carefully carried on.

Notwithstanding the fact that phosphorus cannot be eliminated in the ordinary Bessemer converter, enormous quantities of steel have been made by this process, and within the last two or three years means have been devised by which this bugbear of steel makers has been overcome. I refer to what is known as the Thomas-Gilchrist or "basic" process.

In the ordinary Bessemer converter the lining is formed of ganister, a siliceous material. Now, silica has a greater affinity for oxide of iron than phosphoric acid has, consequently, so long as free silica is present phosphoric acid cannot remain in combination with oxide of iron; whilst, then, the lining of the converter was of silica, it is sufficiently obvious that phosphoric acid could never be eliminated.

You will at once say, why line the converter with this objectionable substance? The answer is easy—No substitute was known, and the reason why phosphoric acid was not removed was not generally understood.

This was the state of things when Messrs. Thomas & Gilchrist commenced their experiments. The object they had in view was to substitute for the ganister a basic material, such as lime. The difficulty they had to contend with was to obtain a lining which would hold together. After many failures and much patient labor, a material has been found which fulfills the necessary conditions. This material is magnesian limestone; by grinding it and mixing it with pitch, bricks can be formed, which, after burning, are very refractory. In lining the converter it was impossible to cement the bricks satisfactorily together; they generally get a good deal curved in baking, and fit badly together, and the cementing material is easily washed out by the molten metal. In order to get over this difficulty, the converters have been lined by running the material in, and then drying and heating in stoves the various pieces of which the converter is composed. This method has proved to be more successful.

From an enemy, by judicious treatment, we may be said to have converted phosphorus into a friend. In the acid process, it is essential that about 2 per cent. of silicon should be present, for it is, to a great extent, due to the presence of silicon, that the requisite high temperature can be obtained. In the basic process, the less silicon there is the better; because it destroys the lining by fluxing it away. Here it is that the phosphorus befriends us, for it, too, is capable of producing a high temperature by combining with oxygen; and that being the case, it becomes possible to work with about half the silicon necessary in the acid process, which practically means that we may employ a much lower grade of iron; for the lower the grade of iron, the smaller will be the amount of silicon in it.

So appreciated has this hitherto despised substance become, that it is actually the practice to put back into the blast furnace a great part of the slag from the converter, in order to increase the amount of phosphorus in the pig iron, subsequently to be converted into steel.

There is, however, a limit to the lowness of grade of iron which can be used, for, although the silicon decreases, the sulphur increases, and only about half the sulphur present in the pig iron can be removed in the converter. One-tenth per cent. of sulphur suffices to prevent steel from rolling in a sound condition. As I have already pointed out, the way to counteract the influence of sulphur is to employ manganese in sufficient quantity, but this is not without a drawback, for manganese is expensive.

In working out this process, much difficulty was at first experienced, owing to the mouth of the converter getting gobbed up, that is to say, stopped by projected slag. The basic slag, consisting as it does principally of lime, is very pasty. This inconvenience has been successfully got over by employing converters of the form shown on the diagram. It was predicted by many, that the slag and metal would be thrown out of the mouth of this form of converter; but that has not been the case, and it is not improbable that eventually this shaped vessel will be universally adopted for both the acid and the basic processes. Such is already the case at Messrs. Bolckow, Vaughan & Co.'s works, where, under the intelligent and persevering guidance of Mr. Windsor Richards, the basic process has first been made a commercial success in this country.

One word as regards the silicon, which, we have seen, is useful as a combustible in the Bessemer process. This substance produces both red and cold shortness in steel, which has to be worked, if present, in even so small a quantity as two-tenths per cent. But in the production of sound steel castings, it has been found to exert a very beneficial influence by preventing the metal from becoming honey-combed by escaping gases while solidifying. It exerts its influence by combining with oxygen, which would otherwise unite itself to carbon, and form a gaseous compound; the silica thus produced passes rapidly into the slag in combination with manganese, which is introduced at the same time as the silicon in an alloy containing them both.

In consequence of the extremely high temperature which we can command, either in the Bessemer or open-hearth processes, it is possible to obtain in a molten state metal practically free from carbon, or containing carbon to any required amount. It is sufficiently obvious that, having regard to the original and commonly understood meaning of the word steel, some other name should, strictly speaking, be applied to all metal manufactured by these processes, which cannot be hardened and tempered. In practice, however, there are many obstacles in the way of this being done, and it has become customary to designate by the term steel all the metal which has been produced in a molten condition by the Bessemer or open-hearth furnaces.

It thus has resulted that we speak of steel ships, steel boilers, and steel rails. The metal of which ship plates are made contains about $\frac{1}{10}\frac{3}{0}$ths per cent. of carbon, that for boilers about $\frac{2}{10}\frac{4}{0}$ths, while rails usually have about $\frac{4}{10}$ths. The first and the second could not be appreciably hardened, and the third is considerably below what would formerly have been considered steel.

Although, then, metal possessing the true characteristics of steel can be made by these processes, yet that which is ordinarily made is not steel, but a metal called into existence by our recently acquired power of obtaining an extremely high temperature.

This new metal, as we may fairly call it, has properties far excelling those of wrought iron, and it has only been a question of time to make this universally felt.

At the present moment new iron rails are things of the past, and wooden sleepers have begun to follow in their wake, it having become apparent to all that our new metal will be an economical substitute. So with ships, the wooden walls of old England are no more. Steel has not only supplemented wrought iron where it was used, but the wood also.

At present there is but one sound reason why steel should not universally replace iron with advantage, and that is,

that in some cases it is cheaper to employ iron. Statistics show us that the enormous quantities of steel now manufactured have but little, if at all, affected the production of wrought iron. It is, however, I am convinced, but a question of time. When the day comes, and every day brings us nearer to it, when steel will be manufactured as cheaply as iron, then will wrought iron be a thing of the past amongst the great civilized nations.

One word as regards the employment of steel made by these modern methods for cutlery. Cutlery manufacturers would tell you that it is useless for the purpose; nevertheless, on the Continent, it is very largely used, and in this country to a considerable extent. I do not hesitate to assert that, with suitable ores and proper care in the manufacture, steel well suited for cutlery can be made both in the open-hearth and the converter. The essential in the ore is that it should not contain phosphorus; with but a trace of phosphorus present, a good cutting edge could never be obtained.

I have endeavored to show you this evening in what progress has really consisted, and how it has been brought about. If we glance back for a moment, we see that the open-hearth processes embody the same principle as the first process by which steel was produced, viz., the mutual action of carburized iron and oxide of iron on one another, and the Bessemer process is, after all, though a splendid offspring, only the natural descendent of the finery process, the origin of which, as we have seen, was due to modifications in the primitive blast furnaces. There is perfect continuity throughout, and, after all, what more natural? Progress in the art of manufacturing steel has been the joint work of the scientific chemist and the engineer. As in the past, so in the future, success will depend upon these two elements working harmoniously together.

RIVET HOLES IN STEEL PLATES.

From "Engineering."

Our information respecting the relative effect of punching and drilling steel plates of different thicknesses has just received a valuable addition in the form of the results of an extensive series of experiments carried out under the direction of the Board of Trade, these results being embodied in a "Memorandum," by the engineer surveyor-in-chief, Mr. Thos. W. Trail, which has just been published for the use of the Board of Trade surveyors. The "Memorandum," which is signed by Mr. Thomas W. Trail, Mr. Thomas J. Richards, and Mr. Peter Samson, relates to the strength of steel plates and angles as ascertained by the application of tensile, bending, and bulging strains, &c., to the effect of different modes of forming rivet holes, to the strengths of different constructions of riveted joints, and to the efficiency of different modes of staying the flat surfaces of boilers made of steel plates; for the present, however, we propose to confine our attention to that section relating to the relative effects of punching and drilling rivet holes, leaving the other sections for subsequent notice.

The first series of experiments with which we propose now to deal were made to determine the relative effects of drilling, punching without annealing, and punching followed by annealing, and the plates experimented upon were of four different thicknesses, namely, $\frac{1}{4}$ in., $\frac{1}{2}$ in., $\frac{3}{4}$ in., and 1 in. The testing was all performed by Mr. Kirkaldy, and the specimens dealt were all of large size, being 12 in. in width at the portion where the holes were formed. The drilled samples were drilled by Mr. Kirkaldy, the diameters of the drilled holes being made to correspond with the diameters of the punched holes at their smaller ends, while the punched samples, and those which were punched and subsequently annealed, were prepared by Messrs. J. and G. Rennie, the punches and dies used being those ordinarily employed on their works. The plates were all sup-

plied by the Steel Company of Scotland, the steel being made by the Siemens-Martin process, and samples cut from two plates of each thickness being tested. The samples were, as we have said, 12 in. wide at the part where they were perforated; at the ends their width was increased, and these widened portions were each held between other steel plates by nine tightly fitting pins passing through bored holes, these pins being so arranged as to give a fair distribution of strain throughout the width of the sample. In the case of the $\frac{1}{4}$ in. and $\frac{1}{2}$ in. plates, each sample had its central portion pierced by 12 holes .79 in. in diameter and 2 in. pitch, these holes being disposed in two rows, six in each, and the rows being 2 in. apart from center to center. In the case of the $\frac{3}{4}$ in. plates the samples cut from one plate had also the holes disposed as above described, while those from the other plate were pierced with eight holes 1.08 in. in diameter and 3 in. pitch, disposed in two rows, four in each, the rows being 3 in. apart from center to center. Lastly, in the case of the samples of 1-in. plate, the two drilled test pieces were pierced in the two modes adopted for the $\frac{3}{4}$-in. plates, while the punched, and the punched and annealed samples were all perforated in the same manner as the $\frac{1}{4}$ in. and $\frac{1}{2}$-in. plates. In the case of the samples perforated with the holes 0.79 in. in diameter, 60.5 per cent. of the original area of the plate remained in each line of holes, while in the case of the specimens pierced with 1.08 in. holes, the metal remaining was 64 per cent. of the original area.

In the tables of results Mr. Kirkaldy gives the stresses "per square inch of gross area at holes," this perhaps somewhat ambiguous expression meaning the stresses per square inch of the original sectional areas of the specimen before the holes were formed. The average results are tabulated in the "Memorandum" as follows:

Specimens.	Ultimate stress per sq. inch of gross area at holes.			
	$\frac{1}{4}$ in.	$\frac{1}{2}$ in.	$\frac{3}{4}$ in.	1 in.
	tons.	tons.	tons.	tons.
Drilled	21.9	19.6	19.65	18.3
Punched	19.3	16.65	15.8	13.45
" and annealed.	20.15	18.55	18.7	17.8

This summary shows three principal facts very clearly, namely, first that the drilled specimens were decidedly superior to those which were punched; secondly, that the injury done by punching was to a very great extent removed by subsequent annealing; and third, that the difference in strength of the drilled and punched specimens was materially increased with an increase in the thickness of the plate, or in other words that the thicker the plates the greater was the injury done by punching.

Although, however, the mode of comparison adopted in the above table has certain conveniences, yet it is less useful for general purposes than one founded on the stresses on the sections of metal left between the holes. These stresses have been calculated from Mr. Kirkaldy's figures by the authors of the "Memorandum," and we give below the table containing the summarized results. In giving this we should state that in calculating the net area of plate the diameter of the punched holes has been taken as the diameter at the *small* end; in other words, it has been taken as the diameter of the rivets which the punched holes would accommodate. This mode of taking the diameter of the holes naturally tells against the thicker plates, as the thicker the plate is the greater is the effect of the taper of the holes made by the punch in reducing the section. This must be borne in mind in examining the results recorded. The "Memorandum" before us, however, does not afford the data for enabling us to give to the effect of the taper of the punched holes any absolute value for comparison. The following is the table:

Specimens.	Mean stress per square inch of net section between holes.			
	$\frac{1}{4}$ in.	$\frac{1}{2}$ in.	$\frac{3}{4}$ in.	1 in.
	tons.	tons.	tons.	tons.
Drilled	36.21	32.44	31.64	29.42
Punched	31.94	27.53	24.6	21.02
" and annealed.	33.41	30.75	30.05	27.82
Solid plates	31.65	29.15	29.7	27.7

The results shown in this table, as far as the general relative effect of drilling and punching and the influence of thickness of plate are concerned, are identical with those to be derived from the table

previously given; but there is in addition another important feature shown, namely, the effect of the perforations in increasing the power of resistance of the metal left between the drilled holes, as compared with an unperforated plate. Thus, with drilled holes, this gain in strength amounted in the case of the ¼ in. and ½ in. plates to 13.8 and 11.1 per cent. respectively, while for the ¾ in. plates it was 6.4 per cent., and for the 1 in. plate 6.1 per cent. This increase of ultimate strength, due to a specimen being reduced to its smallest section only for a small length, has for some time been a well-known fact, and it appears to be the more marked the softer or more ductile the material is. It may be remarked here that recent experiments on riveted joints in steel plates have shown that to secure maximum strength, the proportion of rivet area to net area of plate between rivet holes must be considerably greater than in iron, and judging from the facts that we have just been recording, it appears probable that this result is, in a considerable measure, due to the access of strength to the portions of the plate left between the rivet holes, this gain of strength necessitating an increase of rivet area to balance it, and to secure a maximum strength of joint. The sudden variation in this gain of strength, which accompanies the increase of the thickness of the plates from ½ in. to ¾ in., is very singular and difficult to account for without further experimental data. In the case of the plates which were punched and subsequently annealed, there is also in the case of the ¼ in. and ½ in. plates a marked gain of strength between the holes, while there is also a gain, but a very small one, in the ¾ in. and 1 in. samples. With the punched holes, not annealed, there is in the case of the ¼ in. plates a gain of 1 per cent. in the strength between the holes; but with the other thicknesses there is a decided loss, this loss amounting in the case of the 1 in. plates to as much as 24.2 per cent. In fact these experiments show very strongly how greatly thick plates are injured by punching, but they also show with equal clearness how the injury thus caused is almost entirely removed by proper annealing. It is however essential that the annealing should be carefully and thoroughly done.

Another point shown by the table last given is the superior strength of thin as compared with thick steel plates, even when unperforated, an exception to the regular gradation of strength being, however, shown by the ½ in. and ¾ in., the latter of which is somewhat stronger than the former. It would be of considerable interest to know the sizes of the ingots from which the plates experimented upon were rolled. It is now very generally admitted that to obtain the best results with steel plates, the ingots used must have dimensions which are large multiples of the final thickness of the plate, and the use of exceptionally large ingots for plate making has long been an important feature in the very successful practice of Mr. F. W. Webb, at the London and Northwestern Railway Works at Crewe. It follows from this fact that to get equal final results, the thicker the plate to be produced the larger the ingot should be so as to secure the necessary amount of "work" on the metal during the process of manufacture. Bearing this fact in mind it would, as we have said, be of much interest to know to what extent the strength of the plates tested for the Board of Trade was affected by the relation between the final thicknesses of these plates and the dimensions of the original ingots, although judging from other recorded facts the superior tensile strength of the ¼ in. plates appears to have been largely due to their greater hardness, as we shall see presently.

Another matter of importance brought out by the experiments under notice is the relative elongation of the punched and drilled holes before fracture occurred. We subjoin a table which summarizes the mean results obtained, and it will be observed that the figures there recorded show for the ½ in. and ¾ in. plates a ductility considerably superior to that of either the ¼ in. or the 1 in. plates. In the "Memorandum" before us particulars are given of the testing of unperforated samples of plates, and in these the same feature is also to be noticed, the ultimate extensions in 10 in. length of the ¼ in., ½ in., ¾ in. and 1 in. plates being respectively 17.2, 26.9, 26.0 and 24.4 per cent. The ¼ in. plates thus appear to have been of considerably

plied by the Steel Company of Scotland, the steel being made by the Siemens-Martin process, and samples cut from two plates of each thickness being tested. The samples were, as we have said, 12 in. wide at the part where they were perforated; at the ends their width was increased, and these widened portions were each held between other steel plates by nine tightly fitting pins passing through bored holes, these pins being so arranged as to give a fair distribution of strain throughout the width of the sample. In the case of the ¼ in. and ½ in. plates, each sample had its central portion pierced by 12 holes .79 in. in diameter and 2 in. pitch, these holes being disposed in two rows, six in each, and the rows being 2 in. apart from center to center. In the case of the ¾ in. plates the samples cut from one plate had also the holes disposed as above described, while those from the other plate were pierced with eight holes 1.08 in. in diameter and 3 in. pitch, disposed in two rows, four in each, the rows being 3 in. apart from center to center. Lastly, in the case of the samples of 1-in. plate, the two drilled test pieces were pierced in the two modes adopted for the ¾-in. plates, while the punched, and the punched and annealed samples were all perforated in the same manner as the ¼ in. and ½-in. plates. In the case of the samples perforated with the holes 0.79 in. in diameter, 60.5 per cent. of the original area of the plate remained in each line of holes, while in the case of the specimens pierced with 1.08 in. holes, the metal remaining was 64 per cent. of the original area.

In the tables of results Mr. Kirkaldy gives the stresses "per square inch of gross area at holes," this perhaps somewhat ambiguous expression meaning the stresses per square inch of the original sectional areas of the specimen before the holes were formed. The average results are tabulated in the "Memorandum" as follows:

Specimens.	Ultimate stress per sq. inch of gross area at holes.			
	¼ in.	½ in.	¾ in.	1 in.
	tons.	tons.	tons.	tons.
Drilled	21.9	19.6	19.65	18.3
Punched	19.3	16.65	15.8	13.45
" and annealed.	20.15	18.55	18.7	17.8

This summary shows three principal facts very clearly, namely, first that the drilled specimens were decidedly superior to those which were punched; secondly, that the injury done by punching was to a very great extent removed by subsequent annealing; and third, that the difference in strength of the drilled and punched specimens was materially increased with an increase in the thickness of the plate, or in other words that the thicker the plates the greater was the injury done by punching.

Although, however, the mode of comparison adopted in the above table has certain conveniences, yet it is less useful for general purposes than one founded on the stresses on the sections of metal left between the holes. These stresses have been calculated from Mr. Kirkaldy's figures by the authors of the "Memorandum," and we give below the table containing the summarized results. In giving this we should state that in calculating the net area of plate the diameter of the punched holes has been taken as the diameter at the *small* end; in other words, it has been taken as the diameter of the rivets which the punched holes would accommodate. This mode of taking the diameter of the holes naturally tells against the thicker plates, as the thicker the plate is the greater is the effect of the taper of the holes made by the punch in reducing the section. This must be borne in mind in examining the results recorded. The "Memorandum" before us, however, does not afford the data for enabling us to give to the effect of the taper of the punched holes any absolute value for comparison. The following is the table:

Specimens.	Mean stress per square inch of net section between holes.			
	¼ in.	½ in.	¾ in.	1 in.
	tons.	tons.	tons.	tons.
Drilled	36.21	32.44	31.64	29.42
Punched	31.94	27.53	24.6	21.02
" and annealed.	33.41	30.75	30.05	27.82
Solid plates	31.65	29.15	29.7	27.7

The results shown in this table, as far as the general relative effect of drilling and punching and the influence of thickness of plate are concerned, are identical with those to be derived from the table

previously given; but there is in addition another important feature shown, namely, the effect of the perforations in increasing the power of resistance of the metal left between the drilled holes, as compared with an unperforated plate. Thus, with drilled holes, this gain in strength amounted in the case of the ¼ in. and ½ in. plates to 13.8 and 11.1 per cent. respectively, while for the ¾ in. plates it was 6.4 per cent., and for the 1 in. plate 6.1 per cent. This increase of ultimate strength, due to a specimen being reduced to its smallest section only for a small length, has for some time been a well-known fact, and it appears to be the more marked the softer or more ductile the material is. It may be remarked here that recent experiments on riveted joints in steel plates have shown that to secure maximum strength, the proportion of rivet area to net area of plate between rivet holes must be considerably greater than in iron, and judging from the facts that we have just been recording, it appears probable that this result is, in a considerable measure, due to the access of strength to the portions of the plate left between the rivet holes, this gain of strength necessitating an increase of rivet area to balance it, and to secure a maximum strength of joint. The sudden variation in this gain of strength, which accompanies the increase of the thickness of the plates from ½ in. to ¾ in., is very singular and difficult to account for without further experimental data. In the case of the plates which were punched and subsequently annealed, there is also in the case of the ¼ in. and ½ in. plates a marked gain of strength between the holes, while there is also a gain, but a very small one, in the ¾ in. and 1 in. samples. With the punched holes, not annealed, there is in the case of the ¼ in. plates a gain of 1 per cent. in the strength between the holes; but with the other thicknesses there is a decided loss, this loss amounting in the case of the 1 in. plates to as much as 24.2 per cent. In fact these experiments show very strongly how greatly thick plates are injured by punching, but they also show with equal clearness how the injury thus caused is almost entirely removed by proper annealing. It is however essential that the annealing should be carefully and thoroughly done.

Another point shown by the table last given is the superior strength of thin as compared with thick steel plates, even when unperforated, an exception to the regular gradation of strength being, however, shown by the ½ in. and ¾ in., the latter of which is somewhat stronger than the former. It would be of considerable interest to know the sizes of the ingots from which the plates experimented upon were rolled. It is now very generally admitted that to obtain the best results with steel plates, the ingots used must have dimensions which are large multiples of the final thickness of the plate, and the use of exceptionally large ingots for plate making has long been an important feature in the very successful practice of Mr. F. W. Webb, at the London and Northwestern Railway Works at Crewe. It follows from this fact that to get equal final results, the thicker the plate to be produced the larger the ingot should be so as to secure the necessary amount of "work" on the metal during the process of manufacture. Bearing this fact in mind it would, as we have said, be of much interest to know to what extent the strength of the plates tested for the Board of Trade was affected by the relation between the final thicknesses of these plates and the dimensions of the original ingots, although judging from other recorded facts the superior tensile strength of the ¼ in. plates appears to have been largely due to their greater hardness, as we shall see presently.

Another matter of importance brought out by the experiments under notice is the relative elongation of the punched and drilled holes before fracture occurred. We subjoin a table which summarizes the mean results obtained, and it will be observed that the figures there recorded show for the ½ in. and ¾ in. plates a ductility considerably superior to that of either the ¼ in. or the 1 in. plates. In the "Memorandum" before us particulars are given of the testing of unperforated samples of plates, and in these the same feature is also to be noticed, the ultimate extensions in 10 in. length of the ¼ in., ½ in., ¾ in. and 1 in. plates being respectively 17.2, 26.9, 26.0 and 24.4 per cent. The ¼ in. plates thus appear to have been of considerably

harder quality than the others. The table just referred to is as follows:

Specimens.	Elongation of holes at ultimate stress.			
	¼ in.	½ in.	¾ in.	1 in.
	pr.ct.	pr.ct.	pr.ct.	pr.ct.
Drilled	24.3	37.0	37.6	33.5
Punched	11.7	18.5	11.1	4.3
" and annealed.	27.1	35.1	33.0	29.8

It will be noticed that in the case of the ¼ in. plates the punched and annealed samples actually gave a higher elongation than the drilled specimens, the hardness of the plates apparently having been affected by the annealing. Respecting the figures above recorded the "Memorandum" states: "From the results of the experiments there appears to be no doubt that in the event of the stress on either a ship or steam boiler constructed of this mild steel approaching a dangerous limit, warning would be given by leakage at the rivet holes if the holes were drilled, or the plates properly annealed after punching. The elongation of the punched holes has been shown to be so much less than of the drilled holes or the punched holes when the plates are afterwards annealed, and the punched specimens break so suddenly, that it is doubtful if warning would be given under similar circumstances." With these remarks we entirely agree.

In addition to the experiments with which we have dealt above, the "Memorandum" before us contains particulars of another series, in which the specimens included not only drilled, punched, and punched and annealed samples, but also samples the holes in which had been punched of less than the required diameter and subsequently enlarged by boring. The plates, as in the previous series, were supplied by the Steel Company of Scotland, while the specimens were prepared free of cost by Mr. Halket, the manager of the Glengall Iron Works, Milwall. Thirty-two specimens were prepared in all, namely, eight of each thickness of ¼ in., ½ in., ¾ in. and 1 in., and one specimen of each thickness was drilled, two punched and not annealed, two punched and annealed, two punched small and bored to size, and one left unperforated. For the different thicknesses the widths of the samples were: For the ¼ in. plates, perforated 1.65 in., unperforated 1.17 in.; for the ½ in. plates, perforated 3.32 in., unperforated 2.32 in.; for the ¾ in. plates, perforated 4.95 in., unperforated 3.44 in.; and for the 1 in. plates, perforated 6.66 in. and 6.54 in., and unperforated 4.66 in. The holes in each case had a diameter equal to the thickness of the plates, and two holes were placed in the width of the strip. In the case of the holes first punched and then bored to size, the following diameters were adopted for the punched holes:

Thickness of plate.	Diameter of holes as punched.	Diameter of holes when bored.
in.	in.	in.
¼	13/64	¼
½	33/64	½
¾	49/64	¾
1	13/16	1

As is pointed out by the authors of the "Memorandum," these proportions, although probably fairly representing ordinary practice, are scarcely such as it is desirable to adopt in order to secure the best results with this mode of forming rivet holes. In punching plates for boilers, absolute accuracy cannot of course be insured, and when the plates are brought together it will in many cases be found that unless a larger allowance for boring has been made than the above table shows, it will be impossible to secure both perfectly fair holes, and to insure that each punched hole has a sufficient amount of metal removed from it around its entire circumference. In the case of the specimens for testing, however, this argument of course does not apply. The results obtained with the specimens above described are summarized in the following table:

Specimens.	Ultimate stress per sq. inch of net section.			
	¼ in.	½ in.	¾ in.	1 in.
	tons.	tons.	tons.	tons.
Punched	28.33	25.33	22.94	21.26
" and annealed.	31.6	29.39	29.31	29.12
" small and bored to size.	31.23	30.86	28.81	29.15
Drilled	31.46	31.37	30.23	28.43
Unperforated	30.17	29.69	27.84	28.17

It will be seen from the above table that as far as the ultimate strength is concerned, the boring out appears to be as effective as subsequent annealing in removing the injury due to punching, there being in fact little to choose between the drilled, punched and annealed, and punched and bored-out specimens. When, however, the ductility of the material is considered it will be found that the comparative results are somewhat different, as the subjoined table shows:

Specimens.	Elongation of holes at Ultimate stress.			
	¼ in.	½ in.	¾ in.	1 in.
	pr.ct.	pr.ct.	pr.ct.	pr.ct.
Punched	9.5	12.0	10.6	3.0
" and annealed.	36.5	43.0	35.3	26.0
" small and bored to size	22.0	28.5	22.6	25.0
Drilled	32.0	44.0	32.0	44.0

The results recorded in this table are important, for they show clearly that the plan of punching holes small and then boring them out is decidedly inferior not only to drilling but also to punching and subsequent annealing. It is possible, however, that this difference might have been removed had the quantity bored out been greater. As bearing on this point we may add that the "Memorandum" gives particulars of some experiments on counter sunk holes such as are used on the outer strakes of the hulls of vessels, the countersinking being continued right through the plate. In the case of these specimens it was found that the ultimate strength was practically the same whether the holes were wholly drilled or whether they were punched and subsequently countersunk, but in the matter of extension before fracture there was a decided advantage in favor of the holes wholly drilled.

The experiments recorded in the "Memorandum" bring out in a very striking light the effect of perforations in modifying the ultimate extension of a sample under strain, this extension being principally localized to the neighborhood of the holes. Thus in the case of the ¾ in. plate (which is a fair specimen of the average results) a 10 in. length perforated by punching elongated but 0.8 per cent. under a strain of 50,000 lbs. per square inch of net section, while under the same strain the punched and annealed specimen elongated 1.55 per cent.; the punched and bored 1.05 per cent.; the drilled 1.5 per cent.; and the unperforated 4.6 per cent. Under a strain of 60,000 lbs. per square inch of net section the punched specimen broke, and the elongations for the others became: punched and annealed 3.85 per cent.; punched and bored 3.5 per cent.; drilled 3.9 per per cent.; and unperforated 12.4 per cent. As the authors of the "Memorandum" point out, these figures show that any attempt to determine the strain upon a boiler shell when under pressure, by measuring the circumferential elongation of the shell plates, must be open to great doubt, it being difficult, if not impossible, to make the necessary allowance for the localization of the extensions at the lines of perforation. Altogether the "Memorandum" we have been considering affords much very useful information, and we propose in another article to deal with some of the other branches of experimental inquiry, of which it records the results.

THE PHENOMENA OF EXPLOSION.

From "The Engineer."

In the present day explosions may be said to play a large part in the world's business and pleasure. Gas engines depend on explosions for their action. Whenever a shaft has to be sunk, a quarry opened, or a tunnel driven, recourse is had to gunpowder or dynamite. We need say nothing of great guns. As for small arms, the sportsman is absolutely dependent on the explosive power of gunpowder for the killing of game. At every turn we find explosions either purposely induced by elaborate contrivance; or intruding themselves on our

notice unsolicited, and, indeed, after every precaution has apparently been taken to avoid their recurrence. It can not be said that the phenomena of explosion are unfamiliar; and considering all the circumstances, it is not a little strange that hardly any sufficient thought has been given to the phenomena by scientific men, and that we may seek in vain for trustworthy and complete theory of the action of explosives. We have no intention of attempting to supply what is wanting. We write now in the hope that those who have the time and the means, and the requisite skill, will devote their attention to the subject, investigate the phenomena of explosion, and give us some definite information, which can hardly fail to prove useful. To this end we propose here to place before our readers certain considerations which lead up to queries, which may or may not admit of being answered.

When a mixture of hydrogen and oxygen is ignited, an explosion takes place, and water results. Two atoms of hydrogen H—O—H combine to form water. Two volumes of hydrogen combine with one volume of oxygen to form two volumes of aqueous vapor. If more than the right proportion of either gas be present, an explosion will nevertheless take place, but there will be left just as much of either gas as was present in excess. Thus if 100 measures of hydrogen were mixed with 80 measures of oxygen, there would, after explosion, be 30 measures of oxygen left, quite pure—as far at least as hydrogen is concerned. If we ask what takes place during explosion, we can obtain no answer, save that there is, first, a great dilation of the gas attended with the evolution of light and heat, subsequently a reduction of pressure, and, lastly, a very great reduction of pressure, as the steam formed in the first instance is condensed. It would appear from what we have said that it is impossible to make hydrogen and oxygen combine to form water without an explosion. This idea is supported by the fact that the well-known singing noise made when hydrogen burns in air is attributed to the rapid succession of a multitude of minute explosions. On the other hand, however, there is some reason to believe that the mixture can be made to flame quietly without any approach to an explosion, as, for example, in a Bunsen burner, or, indeed, in any ordinary gas jet; and it should be borne in mind that in the laboratory the combination of the two gases is generally effected by the electric spark. When gun cotton is inflamed a somewhat complex chemical reaction takes place, akin in some respects to that occurring when gunpowder is burned. But gun cotton presents a peculiarity of very great importance, namely, that if ignited in one way it will burn rapidly away without exploding, whereas if it be ignited in another way it explodes with great violence. Dynamite behaves in much the same manner, and can at will be made either to explode or to burn quietly. The importance of these facts will be seen when we ask is it not possible that many other things besides dynamite and gun cotton may or not be explosive according to the way in which they are ignited? Fine flour dust or stive can, there is every reason to believe, be burned quietly or made to explode with great violence according to circumstances; and it is not impossible that the same statement may be quite true of mixtures of air and coal gas in mines or gas mains.

As to the conditions determining explosion or not in gun cotton, to which for the moment we may confine our attention, they are well known. A cake of wet gun cotton can hardly be induced even to burn; but if a percussion cap be caused to detonate in the cake, the whole will explode with just as much violence as though the cotton were dry. Before we can attempt to arrive at an explanation of the cause of this somewhat puzzling phenomenon, it is necessary to know why gun cotton explodes at all. We have already referred to explosions of mixtures of hydrogen and oxygen, and we have done this advisedly, because such explosions are typical. With certain comparatively unimportant exceptions, all explosions are caused by the combination of oxygen with something else. In gunpowder we have the oxygen of the nitrate of potash uniting with the charcoal and sulphur. The formula of gun cotton is probably $C_{24}H_{21}O_{29}NO_4$; what precisely takes place during explosion is not certainly known, but we have at all events hydrogen and carbon ready

to form a new combination with the oxygen. The basis of gunpowder, gun cotton and dynamite—nitroglycerine—is nitric acid, NO_3H, and nitric acid gives explosive vitality to its compounds solely by virtue of the ease with which it gives up oxygen; in fact nitric acid is, broadly stated, a very unstable compound of oxygen and nitrogen. It is the most easily decomposed of all the acids, and cannot be kept pure in the sun's rays, the actinic rays causing it to give off oxygen. It is accordingly one of the most powerful oxidizing agents known. Powdered charcoal will burst into flame if a little strong nitric acid be dropped on it, and many experiments are well known to every student of chemistry proving the same thing. When nitric acid is employed to produce an explosive, it appears that nitric peroxide NO_2 is substituted for an equivalent of hydrogen, and NO_3 is an excessively unstable compound, giving up its oxygen on the smallest provocation. We have stated that there are certain comparatively unimportant exceptions to the rule that oxygen is always present in explosions. As one exception we may refer to chlorine, which is competent to play much the same part as oxygen, and which enters into the composition of some of the most unstable chemical compounds known. We may put these on one side, however, and turn now to what are known as fulminates. One of these is fulminating mercury $2(HgO)$, Cy_2O_2, another is fulminate of silver $2(AgO)$, Cy_2O_2. In both these we have again nitric acid present as the oxidizing agent. The first is readily caused to explode either by heating it or striking it. It is, however, a stable compound when compared with fulminate of silver, which can be exploded by touching it with any hard substance. We may contrast both with another detonating material, namely, fulminating powder, composed of three parts of niter, two of carbonate of potash, and one of sulphur, intimately mixed and dried. If this powder be touched with a hot iron it will burn away slowly; indeed, it is difficult to cause it to burn at all. If a small spoonfull be placed on a sheet of tin over a slow fire, the powder as it heats will gradually assume a pasty condition, then a lambent blue flame will begin to burn on its surface, and then the whole explodes with a report, the tremendous noise of which is out of all proportion to the quantity of powder used, and the explosion is strangely enough practically harmless, and incapable of displacing even a light sheet of tin. We have not been able to find a reference to this powder, giving any information of use, in any work on chemistry. It is mentioned in some books, but that is all. Chloride of nitrogen and iodide of nitrogen are violently explosive. They contain, however, neither oxygen nor carbon, and their effects seem to be due to the sudden liberation of a very large quantity of nitrogen from a very small quantity of the powder. Again, all chlorates—as, for example, chlorate of potash—part with their oxygen more readily than nitrogen, and this is one reason why chlorate of potash is more powerful as an explosive ingredient than nitrate of potash.

Now, what we have said suffices, we think, to prove that combinations exist which can be caused to assume new relations, and to form new combinations either quietly or with explosive violence; and we have further shown that mere mechanical concussion will cause explosion without the application of heat in any shape or form. Again, there is one substance certainly, namely, the fulminating powder, to which we have just referred, which can be made to detonate only by somewhat long-continued heating. We have thus certain forms of matter requiring diverse conditions to bring about identical results. For example, wet gun cotton will not explode, no matter how great the heat to which it is exposed. Heat alone is powerless in this case to bring about the required result; but heat and percussion together, that is to say heat, and what we may call mechanical shock, will induce an explosion at once. The same statement holds true of dynamite. Neither percussion nor heat alone will make it explode, but the combination of the two, as when a small quantity of fulminate of mercury is fired in contact with it, has the desired effect. Thus, then, as we have said, explosions result in some cases from the application of heat alone; in others from the application of percussion alone; and in yet other cases from the application of both

heat and percussion alone; and we have also seen that forms of matter which under ordinary conditions burn slowly or quickly away, can under other conditions be made to explode with awful violence. May we not now ask, are we at all certain that we can identify all the forms of matter which certainly cannot be made to explode under the combined influences of heat and percussion? If we cannot, we may, perhaps, have not far beyond our reach the key to the cause of such events as the flour mill explosions at Minneapolis, and those which occur, alas, too frequently, in our coal mines. If coal or flour dust hangs in the air we have oxygen and carbon in very close proximity. The nitrogen of the atmosphere plays only the part of a diluent; the oxygen has no affinity for it. Let a flame be applied, the oxygen and the coal dust or flour dust may combine quietly and produce a flame. But it is quite as certain that these combinations may produce an explosion, and what is required to bring about the explosion is apparently percussive action of some kind. No doubt the Minneapolis explosions followed each other because shocks followed each other. In the same way it is by no means impossible that a shot fired in a coal mine may play nearly the same part with the mixture of air and gas present as the percussion cap does in a cake of wet gun cotton. When oxygen and hydrogen are exploded in an eudiometer, the electric spark supplies the equivalent of the percussive action necessary to produce that instantaneous combustion, which causes so much mischief when it is effected on a large scale. We might pursue this section of our subject and go on heaping up illustrations of the effect of percussive action on what are known as unstaple compounds, bnt it is not, we think, necessary. The lesson to be drawn from what we have written is that it is advisable to carry out some experiments to ascertain the effect of percussion on compounds believed to be tolerably staple. It may, for instance, be shown, perhaps, that a mixture of coal gas and air which cannot be exploded in the ordinary way may be caused to explode by a detonator. The same experiment may be tried with an atmosphere charged with coal dust or stive. It is obvious that if explosion can be caused in the way suggested something very important in the management of coal mines will have been learned. The study of this department of molecular physics ought not to be delayed any longer.

HYDROGEN AND CARBONIC OXIDE IN IRON AND STEEL.*

By MR. JOHN PARRY, Ebbw Vale.

From "Iron."

In 1867 Professor Graham published his remarkable experiments showing that various metals were capable of absorbing many times their own volumes of H and CO and evolving the same when heated *in vacuo*. As regards iron, Graham found, first, that 46 grammes of clean iron wire, sp. gr. 7.80, heated two hours, evolved 46.85 c.c. gas; one volume of iron had therefore discharged 7.94 volumes gas, of which about two-thirds was carbonic oxide. (2) Another sample gave 7.27 volumes gas, containing about 15 per cent. carbonic acid, the remainder being principally carbonic oxide with hydrogen and a trace of hydrocarbon. (3) The exhausted iron wire was exposed at a red heat to the action of carbonic oxide, and was found to have absorbed 4.15 times its own volume of the gas. Graham states that wrought iron is a metal not likely to contain small quantities of carbon and oxygen in chemical union with iron, and the gas extracted may be partly due to a reaction of these elements upon each other at a red heat. In another experiment, 32 grammes of iron wire, measuring 4.1 c.c., heated in an exhausted glass tube to exclude the idea of the

* Read at the Spring Meeting of the Iron and Steel Institute.

conceivable permeability of the porcelain tube previously used, gave in one hour 29.8 c c., of which 4.44 per cent. was carbonic acid, the remainder being principally carbonic oxide and hydrogen with a trace of hydrocarbon. The metal did not yet appear to be quite exhausted, and in another experiment the extraction of the natural gas was pushed to a greater degree of exhaustion. Thirty-nine grammes thus treated gave in two hours 45 c.c.; in the third hour, 10.85; in the fourth and fifth, 5.65; in the sixth, 0.9; and in the seventh, 0.7 c.c. gas. The iron now appeared nearly exhausted, after the extraction of 63.1 c.c., or 12.55 times the volume of iron used. The mass of exhausted iron wire remaining after the last experiment was heated to redness in hydrogen and cooled gradually in the same gas, and the metal was then freely exposed to air to get rid of any loosely attached hyd ogen. Exhausted again by the Sprengel air pump at a low red heat, the iron gave $2\frac{1}{2}$ c. c. in one hour, but the greater portion came off in the first ten minutes. Analysis showed hydrogen, 2.3; carbonic oxide, 0.2. The iron had therefore absorbed 0.46 its own volume of hydrogen, and it also had become white like galvanized iron. Another experiment gave 0.43 volume of hydrogen absorbed. The same specimen was then treated in carbonic oxide. The gas absorbed amounted to 23.08 c. c., and of this 20.76 proved to be carbonic oxide. Pure iron, then, is capable of taking up at a low red heat 4.15 times its volume of this gas. The iron remained soft, and did not harden on heating and sudden cooling in water; in short, it was altogether unchanged. Graham remarks that the relations of the metal iron to carbonic oxide appear to be altogether peculiar. The intervention of carbonic oxide with charcoal in the process of cementation has long been recognized. The decomposing action of the charcoal has been supposed to be exercised only at the external surface of the metal. The process is not confined to the surface of the metal, but may occur throughout the substance in consequence of the previous penetration of the metal by carbonic oxide; and it would appear that the diffused action of the gas is the proper means of distributing the carbon throughout the mass of iron. Graham having thus first proved the existence of gas in iron, it was thought that a more extended series of experiments on the various kinds of crude iron, steel, &c., might lead to useful results; that it was desirable to accurately determine the quantity and composition of the gases likely to be present, such information being rendered more valuable from the fact that the history of the manufacture of the sample tested could be readily obtained. It was, however, found that the experiments entailed great difficulties; much time was lost ere reliable results could be obtained; and even now, after nearly six years' work, the author is of opinion that this important subject is yet far from exhausted. Quite recently the matter has again attracted attention, and several workers have contributed valuable information on the points investigated by Graham. The author proposes giving as briefly as possible the results obtained by other workers, concluding with a summary of his own researches. Müller obtained by his well-known methods the following results:

	Gas per cent.	Composition of Gas.		
		H.	N.	CO.
1. Bessemer steel rail.....	48	90.3	9.71	0.00
2. Spring steel...	21	81.9	18.50	0.00
3. Steel before addition of spiegel.....	60	88.8	10.00	0.70
4. Steel after do.	45	77.0	23.3	0.00
5. " rail ".	29	76.7	26.9	0.00
6. " before ".	44	80.4	17.7	1.30
7. " rail ".	51	78.1	20.5	0.90
8. Soft steel.....	16.5	68.8	30.8	0.00
9. Siemens-Martin steel.....	25.0	67.0	30.9	2.20
10. Bessemer steel, ingot.....	17.0	92.4	5.3	1.40
11. Same forged..	5.5	73.4	25.1	1.30
12. Blistered Bessemer steel, forged.....	5.0	52.9	48.5	0.00
13. " rolled....	7.3	54.9	45.2	—
14. Bessemer pig-iron.....	15.0	86.5	9.2	4.3
15. " ".	35.0	83.3	14.0	2.5
17. " ".	28.0	81.1	14.8	4.1

This table shows that hydrogen in considerable proportions exists in all kinds of steel. These results are confirmed

by the more recent determinations of Messrs. E. W. Richards and Stead, which are as follows:

	Steel Ingot.				Hammered Iron.	Cast Iron.
	1.	2.	3.	2.	5.	6.
Carbon.....	0.330	0.450	0.170	0.42	0.050	3.65
Manganese ..	0.690	0.400	0.890	1.08	0.700	0.60
Silicon.	0.100	0.040	0.090	1.00	0.150	2.53

	Metal removed.	Gas evolved	Composition of Gas.				
			H.	N.	CO.	CO_2.	O.
No. 1.	28.3	15.6	86.62	13.29	0.32	none	0.37
No. 2.	65.0	48.0	85.35	14.65	—	—	—
No. 3.	42.0	10.5	87.21	11.15	1.64	—	—
No. 4.	41.6	8.66	67.1	30.30	1.60	—	—
No. 5.	12.25	3.46	30.62	69.38	—	—	—
No. 6.	19.60	4.80	52.5	44.90	—	—	—

Mr. Richards states that some if not all the H might have been obtained from the water. No. 4 was drilled with a blunt drill under water; gas obtained, 17.32 cubic inches; composition, H 88.7, N. 10.3. Steel ingots were subsequently drilled in a bath of mercury; the gas obtained was very minute in quantity and proved to be hydrogen. Previous to the publication of the experiments of Messrs. Müller and Richards, the author was under the impression that the presence of hydrogen in steel was rather advantageous than otherwise, the hydrogen serving to neutralize the oxidation which is apt to occur on heating steel in common reverberatory furnaces, and that the bubbles, &c., in steel, were due solely to the carbonic oxide (considering the latter as being insoluble in steel); while, on the contrary, hydrogen is absorbed at a temperature much below the fusing point of steel. It is plainly indicated that the presence of gas in steel cannot be ignored, and the quality or fitness of steel for certain purposes may be determined by the amount of gas it contains. These experiments have reference only to the quantity of uncombined gas—*i. e.*, gas issuing from steel already overcharged, thereby forming bubbles and tending to the production of unsound castings.* It is manifestly necessary to determine the total quantity of gas both combined and uncombined. As regards Bessemer steel, the determination of the absolute quantity becomes of great importance.

Messrs. L. Troost and P. Hautfeuille (*Compt. Rend.*, 482-485, 562-566, 1873), speaking of the gases existing in metals, state that molten iron and steel possess the property of dissolving gases which they evolve in a part as the temperature sinks. The disengagement of gas which is observed in making large castings and in other metallurgical operations is not due to the above cause alone, inasmuch as the phenomena can be produced under circumstances in which the variations of temperature are too slight to affect appreciably the solubility of the gases; and, moreover, the disengagement of gas is attended by changes in the composition of the metal operated upon. Cast iron kept in fusion in a porcelain tube under reduced pressure continued to evolve gas for three days. The same metal fused in an atmosphere of carbonic oxide or hydrogen behaved as in a partial vacuum. The gas given off was in all cases carbonic oxide, and the production of this gas was found to be due to the action of the fused metal upon the porcelain, the metal becoming gradually richer in silicon and poorer in carbon, until in some cases the proportion of silicon amounted to 8 per cent. Messrs. Troost and Hautefeuille made the following experiments with cast iron

* That the formation of honeycomb in steel is due to the presence of uncombined gases is well explained in a recent article in the *Engineer*, and preventive methods are given. 1. Dr. Muller assumes that hydrogen is the primary cause of bubbles, and that it is derived from the moisture in the air blown in, and proposes drying the latter by passing it through burnt lime. 2 To eliminate hydrogen by blowing in CO, which displaces the soluble hydrogen. Carbonic oxide, he says, is insoluble in molten steel. The mechanical or compression methods are also discussed, and it is explained that by certain methods, if the pressure be not sufficient, the center of the ingot is a mass of cavities. The author thinks with the writer that, on the whole, what he termed the chemical method is the best. Perfectly sound castings of nickel and copper are made by means of some chemical reagent. To nickel, phosphorus is added, and presumably also to copper. There seems no reason why a similar process should not be applied to steel. We are aware that to some extent this has already been done by adding silicious pig to the steel, a slag is thus formed and less gas generated. Unfortunately, from causes well understood, this cannot be efficiently done without leaving an injurious excess of silicon. A slag-forming substance, neutral in its effects on steel is required.

containing 1.21 silicon and 5.32 carbon, after 48 hours' heating in a porcelain tube:

Iron contained.....	0.87	silicon	5.32	carbon
24 hours in silicious crucible....	1.07	"	3.90	"
Globule imbedded in crucible.....	3.40	"	—	"
Cast steel containing.	0.10	"	1.54	"
24 hours fusion in Hessian crucible..	0.26	"	0.74	"
2 hours fusion in silicious crucible....	0.80	"	0.70	"

These experiments show that at temperatures above the melting point of cast iron carbide of iron reduces silica. Hence to avoid the introduction of silicon it is necessary to fuse in vessels of lime or magnesia. They further state that these reactions must go on to some extent in the blast furnace and increase the proportion of silicon in the metal produced, but this is not the principal cause. The action of carbide of iron on silica is slow, more especially when highly basic slags are present. The chief cause lies in the action of alkaline metals, which are always present in silicates. A mixture of potassium, carbonate, carbon and iron filings fused together gave cast iron containing 5.16 per cent. silicon and 2.94 per cent. carbon. Cast iron highly heated in a carbon boat in an atmosphere of hydrogen undergoes tranquil fusion; no gas is disengaged, but after it has remained some time in the gas, if the pressure of hydrogen be rapidly diminished, the disengagement of gas is rendered evident by the projection of metallic globules and particles of graphite. If the temperature be suddenly lowered, the metal solidifies during the disengagement of gas, leaving a rough surface. About 500 grammes cast iron heated 190 hours, temperature 800, gave 16.7 c. c. gas, containing CO_2 0.6, Co 2.8, H 12.3, N 1.0; the greater part of the CO, in the first few hours; hydrogen is more forcibly retained. The same iron heated 48 hours in carbonic oxide absorbed 14.7 c. c., gave $1\frac{1}{2}$ c. c. hydrogen, and took 170 hours heating to get this amount of gas. The same sample heated 48 hours in hydrogen absorbed 4.40 hydrogen.* To ascertain the effect of different proportions of carbon in the metal on the solubility of the gases, the following experiments were made:

500. grammes cast steel heated *in vacuo* evolved:

CO_2.	CO.	H.	N.
0.05	1.4	0.5	0.25=2.2 c.c.

500 grammes soft iron—

2.20	10.80	4.4	1.10=18.5 c.c.

These cylinders were heated up to 800°, first in hydrogen, and then in carbonic oxide, and exhausted as before.

		CO_2	Co.	H.	N.	C.C.
Cast steel	1	0.00	0.90	6.4	0.5=	7.8 in hydrogen.
"	2	"	2.00	0.8	0.4=	3.2 in carbonic oxide.
Soft iron	1	"	0.60	1.00	0.3=	13.9 in hydrogen.
"	2	"	13.70	0.2	0.1=	14.0 in carbonic oxide.

Steel retains the last traces of hydrogen much more forcibly than cast iron, notwithstanding that when saturated with the gas it gives off a portion at the ordinary temperature like palladium. Soft iron retains carbonic oxide more forcibly than it retains hydrogen, contrary to what is observed with cast iron and steel.

Simultaneously with Messrs. Troost and Hautfeuille's researches, the author was engaged in determining the gases in iron, &c., according to the method of Graham, with such precautions and modifications of the apparatus as from time to time suggested themselves. In the first series of experiments glass tubes only were used, which only bear a dull red heat. At a higher temperature they collapsed.

	Hours.	c.c.		c.c. gas.
Heated *in vacuo*,	3	1	spiegeleisen discharged	2
" "	$6\frac{1}{2}$	1	white pig iron discharged	2
" "	2	1	grey iron discharged	21
" "	2	1	steel discharged	13
" "	2	1	wrought iron discharged	21

of the following composition per cent:

	CO_2.	CO.	O.	H.	N.
Spiegeleisen (clean lumps)..... ..	0.942	17.87	0.00	81.05	—
White cast iron..	6.800	2.32	"	84.00	6.88
Grey.....	1.600	5.20	"	89.70	3.25
Steel clean drillings.....	16.550	24.352	"	52.01	6.488
Wrought iron bar.	9.92	34.262	"	54.10	1.718

A nearly but not quite perfect vacuum was obtained in the time given. Noting

* Carbonic oxide is much less soluble in iron than hydrogen.

this, it was determined to expose the metal in a good double glazed, double cased, porcelain tube. The tubes used were previously heated *in vacuo*, to remove any natural gas which might possibly be present, to the highest heat (nearly sufficient for the fusion of gray iron) the tube would bear. At this temperature it was found impossible to maintain a good vacuum; the metal continued to evolve gas for a few days, in one instance even after seven days' continuous heating. In the first stage, at a dull red heat gas was evolved freely for about six hours, when it almost ceased. At a bright red it was again rapidly given off for about twelve hours. The iron now appeared nearly exhausted, but an increase of heat had the effect of again starting the flow of gas, and this continued up to the highest heat attainable.

A vacuum can always be formed by lowering the temperature below the point at which the gas is being evolved. Grey iron heated for 165 hours gave 205 times its own volume of hydrogen and 135 times its own volume of carbonic oxide. During 128 hours the proportions of hydrogen and carbonic oxide were as 1 : .90; during the last 36 hours, 1 : .213. Heated in hydrogen, the exhausted iron absorbed only 20 times its volume of hydrogen. Heated in carbonic oxide, no absorption took place.* The gas, after contact with the wrought iron at a red heat, on being examined contained, in one instance, 4½ per cent. of CO_2, and in another 6.00. Bessemer steel analysis—Silicon, 0.080; carbon, 0.35; manganese, 0.72; and 1.02; per cent. of magnetic oxide of iron;† oxygen, 0.281 per cent. Of the oxide of iron obtained, a part equal to 0.26 per cent. proved to be easily soluble in hydrochloric acid. The remaining 0.76 per cent. was insoluble, but proved to be oxide of iron with a trace of manganese. A portion of the same sample oxidized by heating for a short time in the muffle was found to contain oxide of iron, soluble 2.6 per cent.; insoluble, 2.0; total oxygen, 1.26 per cent. Ten grammes of the steel heated *in vacuo* (temperature about the fusing point of copper) gave,

	Gas.		CO_2	CO.	Inflammable Gas, H &c.
1st 24 h'rs	45.0	cont'ni'g	2.58	67.74	29.68 pr.ct.
2d 24 h'rs	41.0	"	0.66	41.80	57.54 "
3d 12 h'rs	5.0	"	1.44	8.39	90.07 "
T'l 60 h'rs	910 c. c.				

Sp. gr. of steel, 7.75. One cubic inch of steel, therefore, discharged 70½ cubic inches of gas. The sample of Bessemer steel previously tested contained more hydrogen. The steel which had been exhausted was heated in an atmosphere of hydrogen, and absorbed in 12 hours 6.6 c.c. or 5.116 vols. The steel again heated twelve hours at a higher temperature, absorbed 7.00 c. c.=5 42 vols. Total, 10.536 times the volume of steel used.*

The evolution of carbonic oxide, in part, at least, appears to be due—1. To the reducing action of carbon on the silicious material of which porcelain is composed. Iron wrapped in platinum, and therefore not in contact with silica, gave considerably less carbonic oxide. 2. Iron and steel may contain oxide of iron which is reduced to the metallic state by carbon with a consequent evolution of gas. The evolution of carbonic oxide may be the result of these reactions, yet Graham affirms that iron contains the gas in solution. It is difficult to conceive how any alloy or combination of iron and carbonic oxide can exist: neither is it probable that either molten iron or steel can absorb or, say, dissolve, the gas without decomposing it. In casting ordinary steel ingots, air is carried down into the moulds entangled in the falling stream of molten metal, and nothing would appear more probable than that a portion would remain imprisoned in the steel, thus forming bubbles. The experiments of Müller and Richards show, however, but little carbonic oxide and only a small proportion of nitrogen, yet more than was found by the author. The quantity of nitrogen in the more recent and perfect experiments was so small, that it was considered doubtful by the author whether iron or steel contained any. Further

*In apparatus constructed to show directly the quantity of gas absorbed by the metal. The indirect method of first heating in a gaseous atmosphere, and then extracting the gas assumed to be absorbed by reheating *in vacuo*, is not reliable, inasmuch as iron and steel always evolve CO as previously stated. Wrought iron and steel were heated in CO with like result.

† Other samples Bessemer steel were found to contain (1) 0.5, (2) 1.6, (3) 2.00, (4) 1.00 of iron oxide.

*Overblown burnt steel gave 7.4 per cent. iron oxide.

experiments are needed to test the truth of Graham's statement. If it can be shown that carbonic oxide is insoluble in iron, it cannot be reckoned as a constituent of either iron or steel.* It must not, however, be forgotten that the presence of oxygen in steel is prejudicial. It is well known that steel contains oxygen, presumably as oxide of iron, and that overheated, burnt, or oxidized steel is a common product.

Hydrogen in Iron.—There can be no doubt that iron and steel are capable of absorbing many times their own volume of hydrogen, which is admitted to be a metal allied to magnesium. It may, therefore, be said to alloy with iron. Matthieson states that in nearly all cases alloys may be defined as solidified solutions of one metal in another. In certain alloys, such as gold and lead, tin or zinc, and some of the amalgams, the existence of chemical combination is indicated. Matthieson, moreover, is of opinion that carbon and iron may be said to form alloys behaving in an analogous manner to other alloys which cannot be looked upon as chemical combinations. No quantitative determinations of hydrogen or other gas have yet been made; all the results given are inconclusive on this point for the reasons previously stated. It is, moreover, very possible that no exhausted vessel heated from the exterior remains perfectly gas tight at the high temperature which appears necessary, although actual results with empty tubes so far disprove this. To remove all uncertainty arising from possible leakage, the author proposes heating the metal (enclosed in an exhausted glass globe) by means of the electric current derived from a powerful battery, or, better still, a dynamo machine. A bar of metal large enough for subsequent mechanical or chemical tests might thus be treated. With a properly constructed apparatus, there would be no errors from leakage due to the possible porosity of the heated tube, thus affording a fair chance of quantitatively determining the hydrogen, &c., evolved. The matter thus volatilized may be examined with the spectroscope with possibly interesting results.

Mr. Lockyer has stated that iron heated *in vacuo* with the spark from a powerful induction coil evolves a vapor, the spectrum of which shows the sulphur and phosphorus lines. It occurred to the author that possibly iron heated in the vapor of metals other than hydrogen might absorb, occlude, or more correctly ally with the metal, and this impression proved to be true. Iron heated in either volatilized zinc, magnesium, cadmium, or bismuth, is capable of absorbing minute quantities of the elements named, which are again evolved on reheating the metal just as with hydrogen; and that these are alloys in the ordinary sense of the term may be inferred from the fact that copper is converted into brass by merely heating it in zinc vapor. Brass, is, of course, only formed on the surface, the interior being copper; but it requires only prolonged action to render the conversion complete. Iron also absorbs in a similar manner both sulphur and phosphorus, but these are not evolved on reheating. With the latter true chemical combinations with iron appear to be formed, which are not decomposed at ordinary temperatures. If we admit this conclusion, it seems that of certain elements contained in iron and steel some may form alloys, as defined by Matthieson, while others may be in chemical combination. It may be inferred that the former class are unstable at ordinary temperatures of fusion, whilst the latter under all known conditions of temperature remain permanent. It need hardly be said that if we admit the above classification of alloys, a wide field for investigation remains to be explored, especially as regards Bessemer steel, and, to begin with, the exact quantitative determination of hydrogen in steel becomes of primary importance; carbonic oxide should also be determined, whether in combination or otherwise, as affording a measure of the quantity of oxygen. Admitting that alloys (with few exceptions) are merely solutions of one metal in another; that to secure an alloy of even composition throughout, the fused mass must be suddenly cooled, and that carbon with some of the metals

* "A new kind of porosity in metals may be imagined of a greater degree of minuteness than the porosity of charcoal and earthenware. This is an intermolecular porosity, due entirely to dilatation on heating; the porosity of iron or platinum is not sufficient to admit of the passage of gas at low temperatures. Under these conditions, carbonic oxide may possibly permeate iron or steel without forming a chemical combination or alloy."—*Deville.*

are simply dissolved in pure iron; it is probable that such a material as cast steel, the temperature at which it is cast and the rate of cooling must largely influence its physical properties. Quick cooling attended with agitation may (as with other alloys) tend to the formation of a homogeneous mass of even chemical composition; slow, undisturbed cooling would have the opposite effect, and these two steels might, on being tested, give results very different. In other words, steel should be as quickly as possible worked into the desired form.

Professor Akerman's statement that carbon may exist in steel in three different states, and Mr. J. W. Spencer's carbon determinations by the color test, showing discrepancies in the same sample of steel according to the mode of treatment, plainly indicate that carbon is simply soluble in iron; and as the amount existing in solution is determined by the method of treatment, it is probable that the insoluble portion has no effect whatever on the temper of the finished steel, but may nevertheless again be dissolved under suitable conditions. Chernoff states that steel, at a temperature varying with the nature of the steel, loses its crystalline structure and becomes amorphous. He maintains that by slow cooling large and regular crystals are formed, while by cooling rapidly, with constant disturbance down to the proper point, a steel of finely-grained structure is obtained, and subsequent cooling has no effect, the latter being of course the better material.

Graham speaks of matter as existing in two forms—1st, the colloid, or amorphous form; 2d, the crystalline form. This statement may be said to be applicable to all bodies, and although Graham speaks of it only in connection with substances fluid at ordinary temperatures, solvents, and gelatinous matter, yet may we not assume that water containing gases and solids in solution is analogous to fluid steel, which is also capable of dissolving gases and solid matter? The temperature may indeed constitute the sole differences between them, water simply existing as such because ice is fusible at the normal temperature of summer, whilst molten steel, at a far higher range of heat, is simply another fluid requiring a certain reduction of temperature ere it becomes solidified or frozen. He states that ice may exist in both the colloid and crystalline form. Colloid ice is formed in contact with water at 0 degrees, and it has the elasticity and tendency to stretch and rend, seen in all colloid or non-crystalline bodies. On the contrary, when it is frozen at a few degrees below zero, it has a well-marked crystalline structure. May we not, then, suppose that something like this occurs in manipulating cast steel; that its structure, more or less crystalline, may depend upon the initial temperature either above or below a zero point, as yet unknown, at which it is solidified? It would seem that steel should be so manipulated as to avoid a crystalline structure, and to approximate as much as possible to the colloid or amorphous state, with all other elements, such as carbon, manganese, &c., uniformly diffused. The author submits the preceding speculations on the molecular and chemical constitution of steel, more with a view of affording matter for discussion than as a definite statement of what may occur under the conditions named.

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—The transactions for April contain:

Paper No. 218. The construction of the Second Avenue Line of the Metropolitan Elevated Railway. By Thomas Hall.

" No. 219. Exponent of the Principle of Moments.

BOSTON SOCIETY OF CIVIL ENGINEERS.—The Committee on Uniformity in Datum Planes presented the following report, the 20th, which was accepted and ordered to be printed:—

REPORT OF COMMITTEE ON UNIFORMITY IN DATUM PLANES.

To the Boston Society of Civil Engineers:

The committee to whom was referred the subject of *uniformity in datum planes for levels* would respectfully make the following

REPORT.

It appears to have been the custom of cities and towns, and also of engineers engaged on public works, to adopt, without any regard to uniformity, some arbitrary datum plane or base to which all levels and heights are referred. Cities and towns located on the seaboard have usually adopted for this plane of reference, so far as the committee have been able to ascertain, either mean high or mean low water, there having been no uniformity of method, however, some adopting one and some the

other, according to the caprice of the engineer at the time the datum plane was established. In some cities two systems even have been adopted and are still used.

The base established by the engineers at the time of the construction of the Boston Water Works (and still used, we understand) was "tide marsh level," or mean high water; but the one subsequently adopted by the first City Engineer, Mr. Chesbrough, for general city purposes (and it is the base used at the present time) was, or rather was intended to be, mean low water. Also, in other cities, the committee understand that different planes of reference for levels have been and are still used by different departments or corporations. This double system of levels in the same locality is very objectionable, and is likely to cause confusion, and may sometimes lead to serious errors.

The committee take this opportunity to protest against any repetition of such a double system where, in the first instance, it can easily be avoided.

The committee do not hesitate to say that, theoretically, some uniform plane of reference for levels would be of great advantage as a means of comparison in different localities; and if such uniformity were to be generally adopted, it appears to them that the *mean level of the sea* would be the most feasible one that could be used for that purpose. Although the mean level of the sea would be the most convenient, if not the only one, that it would be practicable to adopt for a uniform plane of reference, still there are other reasons why mean low water, or extreme low water, or even a lower plane than either, would be found to be preferable in cities and towns located on the seacoast, as it is always desirable to have the base or datum line low enough to avoid the use of minus figures.

In conclusion, the committee would say that after taking the whole subject into consideration, they believe there is no better way of reaching the end, acknowledged by all to be much desired, of uniformity in datum planes for levels, than by the adoption of the *mean level of the sea* for that plane. It will be accompanied by the inconvenience of minus heights, but they believe the mean level of the sea to be the only plane susceptible of being absolutely fixed, and that the *uniformity* and *fixedness* will, on the whole, overbalance the inconvenience.

THOMAS DOANE,
THOS. W. DAVIS,
JOSEPH H. CURTIS, } *Committee.*

Boston, April 20, 1881.

The President invited Mr. Mitchell, whom he observed to be present, to express his views, and he responded as follows:—

MR. HENRY MITCHELL—He fully concurred in the opinion of the committee that the mean level of the sea is the proper datum plane. It is subject to less variation than any other water reference; it is independent of the range of the tide, and essentially so of all the movements of the sun and moon, except *declination*. In our North Atlantic, it is only the declination of the moon that affects the mean level of the sea in any considerable degree, and this amounts to only three inches at Boston. It has been determined, from the long series of observations made by the Coast Survey at the Dry Dock, that with the increase of the moon's declination, whether north or south, the mean level rises. In the Gulf of Mexico, the reverse rule is found to apply, with a maximum change of over six inches.

The unequal pressures of the atmosphere upon different parts of the ocean give rise to changes of mean level; and although it could hardly be expected that the local barometer would be any criterion for this change, it has been pretty well determined that a fall of one inch in the mercurial barometer at Brest is attended by a rise of the mean level of the sea of some sixteen inches; at Liverpool, about ten; and at London, seventeen. On our own coast the change is very small.

The mean level rises as we go up a tidal river, precisely as if this river were tideless; but it does not change as we go through arms of the sea or into bays and lagoons. Different tidal systems have the same mean level, as ascertained at the two extremities of the proposed Cape Cod Canal, and on either side of the isthmus separating the Bay of Fundy from the St. Lawrence, or that separating the Atlantic from the Pacific.

While a series of observations extending over a half-year is necessary to determine the elevation of mean high or mean low tide, observations every fifteen minutes for a single calm day at time of mean declination of the moon have been found to give mean level on our coast; and one may feel entire confidence in the average from such very frequent observations, continued from zero to maximum declination of the moon in the stormless month of July. As before said, the sun's declination may be safely neglected.

It would be a good custom to inscribe upon all public buildings some definite elevations above the datum, providing in this way numerous bench marks.

Mr. Mitchell said, in reply to inquiry from the President, that he knew of no public work in the country referred to the mean level of the sea, high or low tide being the usual reference, and that he regarded the action of the committee in this matter as a step forward.

PREVENTION OF SMOKE.—At a meeting of the Society of Engineers, held on Monday evening, June 13th, a paper was read by Mr. A. C. Engert on the "Prevention of Smoke."

The author, in choosing the title of the "Prevention of Smoke," instead of the "Consumption of Smoke," gives it as his opinion that smoke, once produced by the atmosphere and while being carried by the air, cannot be consumed, as every particle is surrounded by a thin film of carbonic acid. When, however, smoke is condensed as soot, heat will liberate the carbon from the acid, and then the former will burn rapidly. If this theory is found to be correct, carbon cannot destroy the germs of disease floating in the air.

For the consumption of smoke, many ingenious and elaborate inventions are on record, but not yet adopted on account of expense and complexity of mechanisms. A simpler apparatus is, therefore, required.

To prevent smoke, the cold air must not be allowed to come in contact with the gases arising from green coals, and, for this purpose, the furnace is, so to speak, divided into two parts. The fire-door is removed from the boiler, and a box fixed on in front. On each side of this box rails are placed inside, on which a plate or shutter may rest, which can be pushed forward or backward as required. When pushed forward it passes within the boiler and drops over the fire bars some 18in., thereby cutting off the draft and preventing the condensation of the gases arising when fresh coals are put on, thus preventing smoke and the cooling of the boiler.

A still more simple apparatus can be made with the same results, if the opening or flue will admit a higher box. The shutters can be cast together in one piece at an angle of about 130°, to hang within the box on two pins or bolts, thus forming a swinging shutter. A rack is attached to the front of the shutter to regulate the movement.

The advantages of this apparatus are—the cooling of the boiler is entirely avoided, the gases are consumed so that smoke is prevented, and there is a saving of from 15 to 20 per cent of heat and coal.

In ordinary open fire grates the same object is attained—viz., the prevention of the cold air from coming into contact with the green coal, by removing the fire-lump, and substituting for it a cast-iron box, which stands out at the back and is open in front only, and which is filled with coal. Within this box is a movable iron plate, which can be forced forward, carrying with it the coals from which the gases have been extracted and consumed by the heat in front, or moved backwards when the box wants refilling. To regulate the draught so that the fire burns brightly in front, a plate is fixed under the grate, coming forward at the bottom. Another plate, resting on pins, is placed on the top of the box to prevent the flame entering the register.

By this simple apparatus a bright fire is maintained in front of the grate, half of the heat usually escaping into the chimney is saved, there is little or no smoke, and the smallest coal can be used, and is, indeed, preferable.

In kitcheners, stoves, and vertical boilers, a similar box to foregoing can be fixed, the movable plate being worked by a lever.

This invention is also of great importance to railway companies, as it can easily be applied to locomotives. A box is placed under the foot-plate, the whole width of the fire grate, and the coals put in from the top. By this means the gases are almost entirely drawn out of the coal and consumed, the result being very little, if any, smoke. To supply the grate, the coal is pushed forward by a movable plate and lever.

Whether applied to furnaces, ordinary open fire-grates, stoves, kitcheners, vertical boilers, or locomotives, the results of this invention, in each case, are a great saving of heat and fuel, and the reduction of smoke to a minimum.

ENGINEERING NOTES.

THE FORTH BRIDGE, AND ITS ARCHITECT.—The fate of the Tay Bridge had the effect of directing public attention to the design, known to be in course of carrying out, for the erection of a still bolder viaduct over the estuary of the Forth; but the more curiosity was felt on this subject, the greater appears to have been the care exercised to prevent any particulars from becoming known. The usual and legitimate sources of information were carefully closed. At last it became known that the project was adjourned *sine die*, and then, of course, it was said that it was useless to inquire into its details.

The memoir of Sir Thomas Bouch, which has just appeared in the sixty-third volume of the Minutes of Proceedings of the Institution of Civil Engineers, has given some of the long-desired information as to the Forth Bridge, at the same time that it has described other works planned and executed by the energetic engineer whose career came to so melancholy a close. In 1864, plans were lodged for the Glasgow and North British Railway, in which it was proposed to cross the estuary of the Forth by a fixed bridge, three miles long. It was to extend from the southern bank to a point called the Stacks, about a mile above Charleston on the Fife shore. The piers were to consist of wrought-iron cyclinders, supported on a wide base on the silt bottom of the river. The bridge was to be 125 ft. above high-water level, and five of its spans, crossing the fair way of the river, were to be of 500 ft. span each.

An experimental pier was prepared and partly sunk in its place, and attracted much attention among professional men at the time. After considerable progress had been made, the project was abandoned, on the failure of Mr. Hodgson's policy as Chairman of the North British Railway. In 1873, however, Mr. Bouch projected a work of a much bolder kind. He removed the point of crossing to Queensferry, where the width was much reduced, but the depth much increased. Taking advantage of the position of the island of Inchgarvie, which is in the middle of the estuary, for the foundation of a central pier, the engineer proposed to cross the deep-water channels on either side by two spans of 1,600 ft. each, at an elevation of 150 ft. above high-water level. The piers were to be formed of iron columns, strongly braced, and the height of each from the foundation was 600 ft. Each span was to be supported by suspension chains, having a deflection of 375 ft., strong lattice girders forming the support of the roadway.

The directors of the several railway companies interested in obtaining a bridge over the Forth consulted a committee composed of Sir John Hawkshaw, Mr. W. H. Barlow, Mr. G. P. Bidder, and Mr. T. E. Harrison. At the suggestion of these engineers, an elaborate analysis

of the design was made by Mr. W. H. Barlow and Dr. W. Pole, assisted on some points by the Astronomer Royal. On the 30th of June, 1873, these gentlemen sent in their report, after examining which the four referees above-named reported:—"It affords us great satisfaction to be able to give our sanction to a work of so imposing a character, and to express our high approval of the skill, scientific research, and practical knowledge which have been brought to bear upon the elaboration of this interesting work."

On a testimony of this unequivocal nature a company was formed, in 1878; the contracts for the Forth Bridge were let, and on the 30th of September in that year the work was commenced. The fate of the Tay Bridge, on the 28th of December, 1879, alarmed the directors. The Board of Trade were awakened to the fact that their own responsibility was likely to become serious, and they made large demands of security; and the Forth Bridge Company resolved to abandon the undertaking, or to wait for a more convenient season for its prosecution.

It is a matter profoundly affecting the credit of the engineering profession in the United Kingdom, that the unhesitating approval of the Forth Bridge by a committee of four engineers should be either justified or retracted. It will be remembered that, with regard to the Tay Bridge, Sir Thomas Bouch had taken the precaution of seeking the advice of some of the same engineers. It not only was proved by the logic of fact, but was clearly to be read between the lines of the evidence, that proper allowances for the possible fury of the wind had not been made in this structure. But while the engineer of the bridge was, no doubt, directly responsible in this matter, it was too much left out of sight that he was not solely responsible. It may even be questioned, considering his large occupation, and the eminence of the men whose advice he sought, and followed, as to the provision to be made against wind, whether he should have been considered as principally responsible. There is an unpleasant aspect of the matter. The public would have been better satisfied if all those who planned, investigated, sanctioned and approved the designs of those two great estuary bridges had taken their fair share of responsibility for the disaster, and not left Sir Thomas Bouch to be crushed by the weight that they ought to have shared with him. Especially has the public a right to expect from the Institution of Civil Engineers some scientific information as to the provisions proper to be made to resist both the fury of the wind and the shocks of the ice in all railway bridges, as well as with regard to the circumstances under which structures proved by the event to be totally unsafe have been designed by engineers, sanctioned by Parliament, built by contractors, examined and passed by the Board of Trade, and overthrown by the ordinary action of a Scottish winter.

On the 29th ultimo, on the motion of Sir C. Forster, the House of Commons resolved to consider, in Committee, on May 2, the repayment of the money deposited as security for the completion of the Forth Bridge Railway. This marks the final abandonment of the scheme.—*The Builder.*

THE SUEZ CANAL.—The shareholders of the Suez Canal Company held their annual meeting on June 9th, at Paris, when the annual report was submitted and approved. A dividend of 21.89 fr. was declared, apart from the fixed interest of 25 fr. The report states that the gross receipts have amounted to 41,820,000 fr., and the gross expenditure to 28,841,000 fr., leaving a net profit of 12,979,000 fr. The most interesting part of M. de Lesseps' report relates to the traffic. During last year 2026 ships, with a tonnage of 4,344,519 tons, passed through the canal. From 1870 till then the figures had been as follows: In 1870, 486 ships and 495,911 tons; in 1871, 765 ships and 761,467 tons; in 1872, 1082 ships and 1,439,169 tons; in 1873, 1173 ships and 2,085,072 tons; in 1874, 1264 ships and 2,423,672 tons; in 1875, 1494 ships and 2,940,708 tons; in 1876, 1457 ships and 2,072,107 tons; in 1877, 1663 ships and 3,418,949 tons; in 1878, 1593 ships and 3,291,535 tons; in 1879, 1477 ships and 3,236,942 tons. The receipts during this period rose from 5,159,000 fr. in 1870 to 28,886,000 fr. in 1875 and 39,840,000 fr. in 1880. Last year 221 ships, with a total tonnage of 353,985 tons, passed through the canal for the first time. Compared with the previous year, this is an increase of 66 ships and 118,371 tons. The Ducal Line, Bird Line, Union Line, Rotterdam Lloyd, and Rubattino Company have each added one vessel to their fleet; the China and Japan Line, the Russian Line, and the Austro-Hungarian Lloyd each two vessels; the Anchor Line, Ocean Steamship Company, and the Peninsular and Oriental Company, each three vessels; the Orient Line and the Ligne Frangaise, connecting Marseilles with the eastern coast of Africa, each four vessels; and the British India Steam Navigation Company, five vessels. A new postal line connecting England and Spain with the Philippine Islands has been started with five ships. A great trade movement has sprung up between Russia and the colonies of the Amoor and island of Saghalien. There are now some twenty vessels carrying on this new traffic independently of the "national fleet," which has also augmented the number of its ships. Two hundred and thirty eight steamers last year carried coal from England to different parts of the far East; fifty-seven carried rails and railway material to Kurrachee, and two vessels from New York laden with petroleum passed through the canal. There were also thirty-five vessels from Australia, two of which were entirely laden with fresh meat preserved in ice, twenty-seven with Chinese and Japanese products bound for New York, and twenty-six vessels which passed through in ballast to receive cargoes awaiting them at Indian ports. The report anticipates from the experience of the present year that it will show a still larger traffic than last year, though last year's return already showed, as above seen, an increase of nearly 40 per cent. on those of 1879. Since January last the British India Company have created a new regular service between England

and Queensland, and all the great regular lines have sent vessels to the traffic. As regards the Ismailia Canal, it has not yielded all the results that might have been expected, owing to the impediments which M. de Lesseps thinks the Egyptian Government, in its own interest, and in performance of its engagements, will soon remove, and in conclusion, as regards the irrigation canal from Ismailia to Port Said, M. de Lesseps has asked the Khedive to authorize him to form an Egyptian Limited Company to carry it out. Meanwhile, he has formed an association of founders to subscribe, without interest, 200,000 fr. necessary for making the studies and preparing the work. The founders have a right to 10 per cent. of the net profits and the reimbursement of their advances when the company is founded. The subscription to this association was immediately covered on the Isthmus, at Cairo, and at Alexandria.

THE NERBUDDA RAILWAY BRIDGE.—A railway bridge of considerable dimensions was opened for traffic in Western India on the 16th ult. This was the new bridge designed by Sir John Hawkshaw to span the Nerbudda River at Broach, where it is about a mile wide. The bridge by which the Bombay, Baroda and Central India Railway has hitherto carried over its traffic was built about twenty years ago, and has shown itself liable from time to time to be damaged by the river floods during the rainy season. Five years ago, 25 out of the 69 spans which constitute it were carried away by a flood, whereupon the directors of the line determined on building the one which has just been completed, and which has taken three years and a half to construct. The Nerbudda is one of the most sacred of the sacred streams of the Hindoos, and it is a saying among them that while it requires three days' bathing in the Saraswati, seven days' in the Jumna, and one day's in the Ganges, to wash away sin, the mere sight of the Nerbudda suffices to purify. The natives do not regard the building of piers for the support of bridges in these streams as in any way defiling them, but rather look upon the bridges themselves as possessing something of a reflected sanctity in consequence. The new bridge over the Nerbudda is 4687 feet long, and the moving dimensions 14 feet wide and 15 feet 11 inches high. The whole cost of the structure (one third of a million sterling), with the exception of some £40,000, has been entirely met out of the surplus earned by the Bombay, Baroda and Central Railway over and above the amount required to meet the guaranteed interest.

THE NEW TAY BRIDGE.—Examination of the foundations of the old bridge convinced Mr. Barlow that it was requisite to make more allowance than had been before done for the scour of the river, and that the safest and best plan would be to put in piers for a double-way bridge entirely independent of the old piers. The erection of the bridge on the slightly altered site will require the construction of two or three short pieces of railway, and from the shore to their junction solid stone piers will be employed. The total length of the new bridge is a little over 10,000 feet, or about two miles. It is similar to the old bridge with regard to the number of large openings. Each pier is opposite a pier of the old bridge. The calculations are made for double the wind pressure that will ever be brought to bear on holding-down bolts. In reply to a question very pertinently put by Viscount Folkestone, Mr. Barlow said that the wind pressure was calculated at 20lbs. per square foot, and that, in point of fact, the design allowed for 56 lbs. pressure of wind and train. This is close upon the allowance made by the American engineers, and is, in our opinion, ample, if it be regarded as a probable strain that is not unlikely to come upon the bridge—the breaking strength being at least double. It would not, in our opinion, be safe if the breaking tension is put at less than 120 lbs. per square foot of surface on which the wind can lay hold, so as to exert a leverage against the resistance; and no doubt this is what is meant by the evidence. The piers are to be solidly connected with the girders. The parapet will be of wrought iron, as a precaution in case of any vehicle leaving the rails. There are also strong balks of timber placed as fenders outside the rails. It is intended to use some portion of the old girders, after proper testing, in the new structure. —*Builder.*

CESSPOOL EMPTYING BY STEAM.—An attempt is being made to supersede the clumsy system of cesspool clearing which has been carried on in England hitherto. Our neighbors in France have long since effected this work in a more cleanly manner, and a company is being formed in England for working a French patent. The managing director, Mr. Thos. Lawrie, invited a number of gentlemen last Tuesday to Priory Park, Kew, in order to inspect the machines and witness their working. The plant consists of a van for carrying the 4-in. pipes, which are of various lengths, some made of galvanized iron, others of thick rubber for turning corners; a number of receivers, made of light steel plates, barrel shaped, and of a capacity of about 3½ cubic yards. They are mounted on framework on wheels, being easily moved by a pair of horses; and a small portable steam engine, to which is attached a vacuum pump to exhaust the air from the receivers.

On the ground (which was kindly lent for the experiments by Mr. McShean) was a cesspool ready for exemplifying working. A pipe was pushed down to the bottom of the pool, and other pipes were very expeditiously joined to it until they reached the receiver, to which the end was affixed. The engine was set to work to exhaust the receiver, and the noxious air, not allowed to escape, was burned or purified by fire; directly this was done the sewage rushed up the pipes into the receiver at the rate of about one cubic yard per minute. A glass top was arranged on one of the pipes in order that visitors might see the rapid traveling of the soil. The pool operated upon was of the average English size—six cubic yards—and the whole work can be done and the workmen ready to leave the premises within half an hour.

The plan is the invention of M. Talard, who commenced working it in Paris and environs last October.

At luncheon afterwards, Mr. Robson, architect, spoke of the complete success of the experiments, and the simplicity of the machinery, laying especial stress on the perfectness of the lever-joint fastening.

Mr. Arthur Cates, surveyor to the Woods and Forests, also expressed his appreciation of the apparatus.

The number of cesspools still remaining, and likely to remain, in England is very large, and it is asserted that Birmingham alone is able to boast of 50,000.

RAILWAY NOTES.

Of the 514 axles which failed during the year 1880, 278 were engine axles, viz., 251 crank or driving, and 27 leading or trailing; 25 were tender axles, 1 was a carriage axle, 192 were wagon axles, and 18 were axles of salt vans. 90 wagons, including the salt vans, belonged to owners other than the railway companies. Of the 251 crank or driving axles, 190 were made of iron and 61 of steel. The average mileage of 182 iron axles was 171,832 miles, and of 60 steel axles 174,039 miles. Of the 446 rails which broke, 336 were double-headed, 85 were single headed, 13 were of the bridge pattern, and 12 were of Vignole's section; of the double-headed rails, 196 had been turned; 216 rails were made of iron and 230 of steel.

A Transaustralian Railway.—The more enterprising of the inhabitants of Queensland are agitating strongly for the construction of a line of railway which shall connect Brisbane with the Gulf of Carpentaria, and, by establishing a port on the north of Australia, shall divert a considerable part of the shipping traffic, and open out the natural resources of the colony. The railway would extend from Brisbane near the 28th, to Point Parker on the 17th parallel, and would therefore run in a northwesterly direction. A short portion of this railway, that from Brisbane to Roma, has been already made, and the problem remains for a poor colony to construct nearly 1000 miles of railroad, with various branches to connect with other railway systems on the continent. If Queensland is poor in money she is rich in land; and the railway, it is urged, would pass through the midst of an almost unequaled grazing country. The area is about double that of New South Wales, or 428,500,000 acres, which, estimated at 6s. 8d. per acre, is worth £142,800,000. The cost of the railway is estimated at £4,000,000, or about 3 per cent. of the total wealth; and it is proposed to make a belt 23½ miles wide on each side of the line at the price above mentioned. No doubt the project is an excellent one, and if the railway were constructed it would be not only of inestimable advantage to Queensland but to the rest of the world, by placing at the disposal of emigrants new homes, and by increasing to a large extent the production of the world. There remains, however, the great difficulty, that of finding purchasers for the tracts that would be offered, especially as the great tide of emigration sets towards the United States, which offer more substantial advantages in many respects than the new and far-removed regions of northern Australia. The route suggested appears to offer many advantages over the projected railway to Port Darwin; and the Gulf of Carpentaria is stated to leave little to be desired as a harbor for large shipping.

Safety Appliances on Railways.—Steady, though very slow, progress is being made towards the complete equipment of our railway system with safety appliances. A return recently issued shows that the number and proportion of cases in which signal and point levers had been interlocked in 1879 and 1880 respectively were:

	1880.		1880.		Percentage interlocked.		Percentage increase in 1880 over 1879.
	Interlocked.	Not interlocked.	Interlocked.	Not interlocked.	1879	1880	
England and Wales	24352	5330	21491	4717	80.	82.	2.
Scotland	2887	1846	3087	1735	61.	64.	3.
Ireland	566	1135	686	1119	32.	38.	6.
Total United Kingdom	23905	8311	25264	7571	47.	77.	3.

Then as to the block system, the number of lines open for traffic, and the distance worked on the absolute block system in each of the two years were:

	1879.		1880.		Percentage of double line worked on absolute block system.		Percentage increase in 1880 over 1879.
	Length of double line open.	Distance worked on absolute block system.	Length of double line open.	Distance worked on absolute block system.	1879	1880	
England and Wales	7809	6803	7980	7128	86.	89.	3.
Scotland	1074	676	1086	773	63.	71.	8.
Ireland	506	94	567	94	17.	17.	nil.
Total United Kingdom	9509	7573	9633	7995	80.	83.	3.

In England, it will be observed, both as regards the interlocking of points and signals and the adoption of the block system, the work is well advanced. In Scotland, however, much lee way has to be made up, and in Ireland the work may be said to have been little more than ommenced.

ORDNANCE AND NAVAL.

THE "POLYPHEMUS."—The completion of the Polyphemus gives a novel and apparently formidable addition to the British Navy, but one that must be regarded as largely experimental until it is submitted to the test of actual warfare. The appearance of the hull suggests that of the Winans cigar ship, but this effect is concealed by the false works and turrets. The vessel is 240 ft. long, and 40 ft. in extreme breadth; the draught of water being 19 ft. 6 in. forward. and 20 ft. 6 in. aft; the displacement is 2640 tons. She is built throughout of steel, and is framed with transverse brackets and continuous longitudinals, and with a double bottom the whole length of the ship. The lower part is subdivided into a large number of cellular spaces, while the whole is divided by a longitudinal bulkhead, and numerous transverse bulkheads, and the engine and boilers are contained in six water-tight compartments. Over the framing of the ship is placed a double plating of Landore-Siemens steel, each plate being ½ in. thick, and upon these is a thickness of Whitworth's fluid compressed steel in plates 10 ft. long, 2 ft. 6 in. deep, and 1 in. thick. The armor plates which cover the whole of the curved deck and sides below the water line are peculiarly arranged. They are also of Whitworth compressed steel, and are made in plates or scales 10 in. square and 1 in. thick. These scales overlap each other in such a way that the securing coned steel plugs, which are placed one in each corner, hold three adjacent plates, there being also one central plug. Forming a part of the rigid structure of the vessel are six steel-clad revolving turrets, three on each side, which will be armed with the heaviest class of Nordenfelt guns. At each end of the ship also there is an armored conning and steering tower, entered from the interior of the vessel. There are also two armor-plated ventilating shafts and a smoke stack. The superstructure reared upon the hull gives to the Polyphemus something of a ship-shape appearance. It consists of a forecastle rising 9 ft. out of the water, a main deck, and a flying deck carrying boats and two large life rafts; this superstructure is of course quite independent of the ship's framing, and may be all shot away without affecting her safety. A special feature in the Polyphemus is the absence of keel, a recess or groove 3 ft. 6 in. deep, 2 ft. 6 in. wide at the bottom, and 2 ft. at the top, being formed along the whole length in the position usually occupied by the keel. This groove is divided into sections by transverse partitions placed across it, each section being large enough to receive a length of cast iron 10 ft. long and weighing about 50 tons. At one end each of these blocks is hooked on to the partition in the groove, and at the other end it is held by a cam attachment operated from the interior of the ship, and which can be instantaneously released, and the block detached. The object of this peculiar arrangement is to enable the vessel to float with a lighter draught should she be damaged in action, or should any other necessity arise for such a measure, a difference of 12 in. or 14 in. being possible if all the 300 tons of ballast thus carried is cast loose. Whether this device will prove satisfactory remains to be tested.

The engines of the Polyphemus were constructed by Messrs. Humphrys, Tennant & Co.; they are horizontal single piston-rod compounds with high-pressure cylinders 38 in. in diameter and low-pressure cylinders 64 in. in diameter, the stroke being 39 in. They are supplied from ten boilers of the locomotive type, with a working pressure of 120 lbs. per square inch. The engines have indicated 5500 horse power, and the estimated speed to be got with them is 17 knots. She will be propelled by three-bladed twin screws 14 ft. in diameter, and from 15 ft. to 17 ft. pitch, and for special manœuvring two bow rudders are provided which can be housed within recesses when not required. A part of the armament of this curious vessel has been already referred to. The Nordenfelt guns mounted in the six turrets will be able to enclose her within an almost solid veil of lead, and no small boat could live within the circle of their fire. But besides this they should be useful within limits for offensive operations also, though of course they would be useless at long ranges or against armor. But the real offensive strength of the Polyphemus lies in the fact that she may be regarded as a gigantic torpedo to be hurled bodily at the top of her speed against an enemy, which if fairly struck would have no alternative but to go down, and as she can be very easily handled, and possesses a high speed she should prove a formidable antagonist in this mode of fighting. The striking weapon consists of a ram projecting about 13 ft. beyond the hull, and placed so far below the water level as to render it most effective against the unprotected hull of an adversary. This ram, which is strongly framed on to the hull and armor plated is terminated by a solid steel spur forming a cap which, when desired, can be turned up, and a circular opening within the ram exposed. From this opening the Whitehead torpedo can be discharged, so that this part of the ship forms not only a formidable weapon for assault but also the appliance whence the smaller implements of destruction will issue. There are, moreover, four other torpedo ports, two on each side near the bows, and spar torpedoes will be carried on deck.

The Polyphemus, which was built at Chatham, and has cost about £150,000, was launched on Wednesday last, with engines and boilers fitted, but without armament, stores, or ballast. She will now be moved into one of the docks of the yard, and her final fittings completed without delay, so that she will probably be ready for trial within two months. It may be well here to recall some remarks made in the House of Commons by the late Mr. Ward Hunt on the 12th of March, 1877, when he was describing the general features of the Polyphemus. He said on that occasion "that this vessel must, of course, to a certain extent, be regarded as an experiment, and even supposing it to be a success, I could not propose it to the House as being likely to supersede all other

kinds of fighting ships, but only as a useful adjunct to a fleet in case of war. Probably it would not be desirable that she should be kept at sea for a long period at a time, but I venture to think she will prove a very formidable weapon, and if she should be a success, she may be regarded as a sort of rival to those monster ships with tremendous armor we hear spoken of as likely to be built in some foreign ports."

A NEW TORPEDO.—Another invention has just been added to the already long list of marine infernal machines. A Roumanian engineer has invented a new description of torpedo or submarine boat, whose peculiarity is that it is capable of manœuvring under water for twelve hours at a stretch. It is able to act at depths of from a hundred feet in rivers to seven or eight hundred feet in the sea. It is able, through the agency of screws, to rise or sink noiselessly, and either suddenly or gradually by successive stages, and can move or manœuvre in any direction. The illumination of the vessel is internal, and enables the officers upon her to see for a distance of a hundred and thirty feet under the water. Upon the surface of the water the vessel is managed and manœuvred as any ordinary ironclad boat. If everything that is affirmed concerning this new torpedo boat is true, it will be a decided improvement upon that most eccentric vessel ever constructed in this country, Polyphemus, launched last Wednesday.—*Iron.*

BOOK NOTICES.

PUBLICATIONS RECEIVED.

PROCEEDINGS OF INSTITUTION OF CIVIL ENGINEERS. Deep Winning of Coal in South Wales. By T. Forster Brown, M.I.C.E., and G. F. Adams, M.I.C.E.

BULLETIN OF THE MUSEUM OF COMPARATIVE ZOOLOGY AT HARVARD COLLEGE. No. 3. On an Occurrence of Gold in Maine. No 4. A Microscopical Study of the Iron Ore of Iron Mine Hill, of Cumberland, R. I. By M. E. Wadsworth.

THE PRINCIPLES OF MYODYNAMICS. By Jarvis S. Wight, M. D. New York: Bermingham & Co.

SECOND GEOLOGICAL REPORT OF PENNSYLVANIA. Report on the Causes, Kinds and Amount of Waste in Mining Anthracite Coal. By Franklin Platt. Harrisburg: Published by Board of Commissioners.

The greater portion of this work is of the thoroughly practical order, which the title clearly indicates; a chapter in the distribution of the anthracite, however, is of more general interest. The process of mining, also, is so lucidly explained, that it deserves publication as a separate essay.

The illustrations are exceedingly numerous and very plain.

NOTE-BOOK OF AN AMATEUR GEOLOGIST. By John Edward Lee, F.G.S., F.S.A. London: Longmans.

For many years Mr. Lee has been in the habit of keeping a note book, in which anything bearing either on geology or archæology might be entered, and as he has evidently been an industrious rambler, the collection of notes and sketches grew to such dimensions that his friends urged him to publish them. The result is that we have a volume which will certainly be found of interest by other amateur geologists, and which will be welcome in the library of the professor of the science. Altogether there are 209 plates of sketches which, intended as aids to the memory, represent what was actually seen at the time. A friend of the late Professor Phillips, to whom he owes much of the information he possesses, Mr. Lee has evidently imbibed much of the spirit of that distinguished geologist, and his "notes" and sketches will be very welcome to many other workers in the same field. The expense attending the production of such a book as this is necessarily great; but Mr. Lee promises that if, contrary to his expectation, the present volume should be so well received that the loss on its publication is not very large, he will probably issue his archæological notes. The sketches cover a wide field, for they show that Mr. Lee has visited many parts of England and Wales, Scotland, Italy, France, Switzerland, Sweden, and other countries. The notes are short and to the purpose, the author's object being merely to describe the diagrams and sketches, not to write a treatise on geology. We think that students of the science will thank him for the publication of his notes, for those who cannot follow the same track will be able to form an opinion of the natural objects depicted, and those who have leisure to make tours will learn from them where to go, and will feel a pleasure in comparing notes.—*Eng. Mechanic.*

A PRACTICAL TREATISE ON MECHANICAL ENGINEERING. By Francis Campin, C.E. London: Crosby Lockwood & Co.

This work is substantially an abridgment of the author's larger treatise; but it has been entirely rewritten, the improvements in mechanical manipulation having rendered obselete many of the processes described in the earlier treatise. "A quantity of descriptive matter has been eliminated, and replaced by accounts of vacuum brakes and other modern appliances," and we must suppose that the author had good reason for eliminating the matter left out; but why he should have given us a chapter on railway and tramway appliances mainly devoted to a description of the Eames vacuum brake and Hardie's tram rail, passes comprehension. Mr. Campin seems to be unaware of the existence of other vacuum brakes and of the Westinghouse automatic pressure brake, and, accordingly, we find the following sentence in this remarkable chapter:—"There is great difficulty in determining the relative efficiencies of brakes, because there have never yet been made any trials which afford information on the subject of any practical value." The author is apparently aware that trials have

been made: but the tables and reports are so "utterly worthless," that it is almost a waste of space to point it out; still, for the benefit of his young readers, Mr. Campin ventures on a little explanation. In the trials referred to, he says "the retarding effects of the train-friction *has* not been taken into consideration,"—a statement which is incorrect in phraseology, as well as in the meaning it is intended to convey.—*Eng. Mechanic.*

MISCELLANEOUS.

COATING OF METALS.—To protect metals against the oxidizing influence of a damp atmosphere has long been an object of research of a great practical importance. It is well known that a bright sheet of zinc, such as is used in covering roofs, very rapidly gets covered by a thin layer of oxide, and that this thin film becomes so thoroughly united to the metal below that it forms a firm coating and protects the metal against further oxidation. A precisely similar object has been followed by several inventors with regard to iron when they endeavored to provide it with an adhering coating of black magnetic oxide of iron. This was idone successfully in 1860 by Thirault, who employed a solution of chloride of iron, which was well rubbed upon the metal and gave it a black luster, when the artificial rust was converted in the black oxide after having been dipped in boiling water. In 1862 a similar result was obtained by Sauerwein, who used besides chloride of iron, chloride of antimony and gallic acid, while another method was to cover the surface of iron with linseed oil and to expose it then to a dull red heat. By the process of Barff, in 1877, such a coating is obtained by subjecting iron at a dull red heat for six to seven hours to dry steam, when a black fast-adhering coating will be formed. More recently another method, of Mr. Bower, came in use, and it is now carried out on a large scale by a French company, the Société Francaise d'Inoxidation, which has its works at Val d'Osne. The coating of the iron articles is produced by first cleansing their surfaces and then by heating them in a furnace to a light red heat, when successively currents of carbonic oxide and carbonic acid are passed through it. In this way a bluish-black oxide of iron is formed upon either cast iron, wrought iron or steel. This oxidized surface, on being polished with oil, takes a beautiful luster, and it is further ornamented by scraping some parts of it free from the coating, which are then either covered with a thin layer of bronze, gold or platinum, by galvanic action, after the invention of M. Dodé. Many articles made by the Société d'Inoxidation, such as statues, vases, fountains, bas-relievos, fire-grates, stoves, balconies, candelabra, railings of staircases, and others, are really of a very beautiful appearance

AT a meeting of the Paris Academy of Sciences, a paper was read "On the Principle of Conservation of Electricity," by M. Lippmann. The principle is expressed by a condition of integrability. In the memoir, the author's method of analysis is applied to various phenomena—dilatation of glass of a Leyden jar during charge, electrization by compression of hemihedral crystals, and pyroelectricity of crystals The existence and law of certain new phenomena, not yet verified, are deduced.

M. GILET DE GRANDMONT repeated to the French Academy of Sciences on Monday last a curious optical experiment. The apparatus consists of a black disc with five apertures: behind this is placed a white or colored disc If the upper part of the disc near the center be regarded fixedly for some seconds, and the colored disc be then rapidly replaced by the white disc, the eye does not perceive the white through the apertures, but the complementary color of the colored disc which has been removed.

THE following paragraph from the preface to "Elementary Lessons in Electricity and Magnetism," by Sylvanus P. Thompson, shortly to be published by Messrs. Macmillan & Co., has been communicated to *Nature* because of the similarity of the views therein to those in a paper by M. Lippmann, published in the *Comptes Rendus* of the 2nd ult. Mr Thompson's MS. was in the hands of his publisher in March last, so that no doubts as to originality need arise: "The theory of electricity adopted throughout is that electricity, whatever its nature, is one, not two; that electricity, whatever it may prove be, is not matter, and is not energy; that it resembles both matter and energy in one respect, however, in that it can neither be created nor destroyed. The doctrine of the Conservation of Matter, established a century ago by Lavoisier, teaches us that we can neither destroy nor create matter, though we can alter its distribution and its forms and combinations in innumerable ways. The doctrine of the Conservation of Energy, which has been built up by Helmholtz, Thomson, Joule, and Mayer, during the last half century, teaches us that we can neither create nor destroy energy, though we may change it from one form to another, causing it to appear as the energy of moving bodies, as the energy of heat, or as the static energy of a body which has been lifted against gravity, or some other attracting force, into a position whence it can run down, and where it has the potentiality of doing work. So also the doctrine of the Conservation of Electricity, which is now growing into shape, but here first enunciated under this name, teaches us that we can neither create nor destroy electricity, though we may alter its distribution—may make more to appear at one place and less at another—may change it from a condition of rest to that of motion, or may cause it to spin round in whirlpools or vortices which themselves can attract or repel other vortices. According to this view, all our electrical machines and batteries are merely instruments for altering the distribution of electricity by moving some of it from one place to another, or for causing electricity, when heaped up in one place, to do work in returning to its former level distribution."